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A SIMULATION ANALYSIS OF THE ECONOMIC CONSEQUENCES OF ESTABLISHING MULTI-MODAL TRANSPORTATION COMPANIES

Robert S. Tripp

Air Force Institute of Technology
Wright-Patterson Air Force Base, Ohio

December 1972

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THE ECONOMIC CONSEQUENCES
OF ESTABLISHING MULTI-MODAL
TRANSPORTATION COMPANIES

Robert S. Tripp, Captain, USAF

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This study is concerned with the examination of the economic consequences of establishing multi-modal transportation companies. ~~More specifically,~~ the purpose of this research is to: ~~(1)~~ examine the economic impact various combinations of parameters or test factors have on a transportation company formed from single modal carriers, and (2) determine "on the average" which organizational form, i.e., transportation company versus single modal carriers, is economically superior.

In order to accomplish this goal, a simulation model was developed ~~which~~ made the comparison of a transportation company with single modal carriers ~~possible.~~ Within this framework, the economic performance of the two organizational approaches was contrasted for both TL/CL and LTL movements. The test factors ~~which~~ were selected for analysis are: (1) the operating ratios of ~~the forming modes~~ (truck and rail), (2) the load factors of the forming modes, ~~(3)~~ the amount of available capacity, (4) and the level of shippers' logistics constraints.

The performance measures which were selected to describe the economic impact of operating a transportation system under the two different organizational approaches are: (1) the expected contribution (to fixed and/or common costs including profit margin), of the carriers, (2) the actual contribution of the carriers, (3) the total price paid for transportation by shippers, and the amount of traffic moved by (4) truck, (5) piggyback, and (6) rail under each organizational approach.

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ABSTRACT

Common ownership has been a subject of debate in transportation circles for years. Unfortunately, while discussion and speculation on the subject have abounded, there has been very little research directed at determining what the potential of a multi-modal transportation company is.

This study is concerned with the examination of the economic consequences of establishing multi-modal transportation companies. More specifically, the purpose of this dissertation is to: (1) examine the economic impact various combinations of parameters or test factors have on a transportation company formed from single modal carriers, and (2) determine "on the average" which organizational form, i.e., transportation company versus single modal carriers, is economically superior.

In order to accomplish this goal, a simulation model was developed which made the comparison of a transportation company with single modal carriers possible. Within this framework, the economic performance of the two organizational approaches was contrasted for both TL/CL and LTL movements. The test factors which were selected for analysis are: (1) the operating ratios of the forming modes (truck and rail), (2) the load

factors of the forming modes, (3) the amount of available capacity, (4) and the level of shippers' logistics constraints.

The performance measures which were selected to describe the economic impact of operating a transportation system under the two different organizational approaches are: (1) the expected contribution (to fixed and/or common costs including profit margin), of the carriers, (2) the actual contribution of the carriers, (3) the total price paid for transportation by shippers, and the amount of traffic moved by (4) truck, (5) piggyback, and (6) rail under each organizational approach.

A fractional factorial experimental design was utilized to analyze the output of the simulation model. Appropriate statistical tests were utilized to: (1) indicate which of the test factors or test factor combinations produced statistically significant behavior in the performance measures, and (2) determine if the performance measures were significantly different for the two organizational approaches.

It was found that most of the average differences of the performance measures between the transportation company and the single modal carriers were significant. More specifically, for TL/CL movements it was found that the expected and actual contribution of the transportation company were significantly greater than the sum of these measures for the single modal carriers. In the LTL category of movements, the expected and actual contribution of the transportation company was again significantly larger than the combined contributions of the single modal carriers. The transportation company also had the effect of significantly reducing the price paid by shippers for LTL transportation services.

The prime consideration of the research was the identification and explanation of the manner in which the levels of the test factors affect the average performance measures. The analysis of the effects produced by the test factors reveals under what operating conditions (test factor levels) the transportation company was "economically superior" to the single modal companies and vice versa.

The economic aspects of the common ownership controversy are, however, but one facet of a multidimensional problem. As such, the research has identified the other aspects of the controversy and discussed their relationship to the results obtained in this study. Although there remain a lot of unanswered questions which must be researched concerning the common ownership question, this study is a step in the direction of obtaining those answers.

CHAPTER I

INTRODUCTION

For quite some time now there has been a continuing controversy in transportation circles about the desirability of establishing multi-modal transportation companies in the United States. The arguments for and against the ownership of one mode of transportation by a competing mode have been stated and restated. The nature of these arguments is illustrated in the following quotation:

> The issues in the common-ownership controversy are basically simple. Major arguments in favor of common ownership are that (1) it permits better service to the customer. Through the availability of coordinated transportation service under the control of a [multi-modal] transportation company, each shipment can be moved by the mode or combination of modes which best fits the requirements of the customer. Common ownership would not reduce effective competition because there would still be many separate mode carriers and several "department stores of transportation" general carriers. (2) There are economies in operation in having one sales force and one operating headquarters in each area handling the transportation service. (3) The customer convenience would be increased because there would be only one set of arrangements required, and a single carrier would be responsible for any loss or damage.
>
> The important arguments against common ownership include: (1) It would stifle competition and result in poorer or more expensive service to the shipper in the long run. The railroads would look to their primary financial investment and divert all possible traffic to their rail operation while using the truck service to drive independent truckers out of business. .. (2) Railroad or other nontrucking managements could not do as good a job of running truck operations because they do not have the special knowledge and experience required for best performance. ... (3) Motor-carrier service would not be developed as rapidly

or as well by common-ownership companies as it would be by managements which had no other interest.[1]

The above listings of pros and cons is not exhaustive, but should give the reader an appreciation for the types of arguments being cast back and forth. While much discussion exists, there has not been any affective research accomplished on the subject of multi-modal transportation companies.

The controversy has been unresolved for several reasons, such as entrenched carrier managements or at least parochial attitudes of carriers concerning their own mode. Furthermore shippers tend to have a short-range perspective toward the transportation plant, trying to obtain the maximum benefits from the existing modes. Another reason why there has been no systematic research on the subject is that the present laws which deal with the transportation company questions or interpretations of those laws by the Interstate Commerce Commission (I.C.C) have been very restrictive.[2] This lack of effective research on the topic has resulted in the fact that today there exist no suitable decision criteria for determining

[1] Gayton E. Germane, Nicholas A. Glaskowsky, Jr., J. L. Heskett, _Highway Transportation Management_ (New York: McGraw-Hill Book Co., Inc., 1963), pp. 403-404.

[2] _Infra_, chapter vi, p. 106.

if the formation of transportation companies would be in the public interest, so the controversy continues.[3]

As indicated in the above arguments the question of whether or not transportation companies should be established is a multi-faceted or multi-dimensional problem. That is, the formation of transportation companies involves economic, legal, and social issues which must be researched to determine the impact such companies would have on the transportation system of the United States. These companies would (most probably) have differing effects on the various groups involved in the movement of goods.

The shippers, carriers, and regulators have differing objectives concerning the transportation system which affect their respective attitudes on the transportation company issue. Shippers desire a low cost, efficient transportation system capable of meeting their needs. Carriers wish to make a good profit in providing transportation services. The regulators sit in the middle between these groups trying to insure that

[3] It might be pointed out that there are some transportation companies in the United States. An example would be the Southern Pacific Company which operates some 26,000 trucking route miles, 14,000 miles of rail lines, and 2,300 pipeline miles (Frank Campanella, "On the Right Track", Barrons, XLVIII, October 28, 1968, p. 9). Southern Pacific retained its trucking operations that were begun prior to 1935 under the "grandfather clause" when Section II was added to the Interstate Commerce Act. Section I is concerned with the regulation of railroads. While it is true that several other railroads own subsidiary trucking companies, the conditions of operating these subsidiaries are severely limited under presently issued I.C.C. certificates of public convenience and necessity, as will be shown in Chapter V.

the needs of both groups are met simultaneously.

This paper will undertake to examine the economic consequences of establishing intermodal transportation companies. The research will be mainly concerned with an analysis as to how the creation of such a company affects the economic well-being of the founding carriers.

Definitions

Before proceeding to describe the nature and intent of the research, and to insure no misunderstanding is created, the following definitions are presented and will be used in the remainder of this dissertation.

Integration of transportation firms involves the purchase or acquisition of a transportation firm of one mode by a transportation firm in another mode. A railroad acquiring a truck line would be an example.

A transportation company is a single firm which owns and operates entities in more than one mode of transportation.

Hence, the integration of transportation firms into a transportation company involves issues of the common ownership of more than one mode of transportation. In the transportation literature the terms common ownership and transportation company are used interchangeably and this practice will be followed in this project.

Coordinated transportation is defined as "a point-to-point through movement by means of two or more modes of transportation on the basis of regularly scheduled operations."[4] Thus coordinated transportation refers to a particular type of transportation service or "product" which is independent of the ownership of the modes. For example, a regularly scheduled piggyback movement, a truck trailer moved on a rail flatcar, is a coordinated transportation movement if the railroad owns the truck trailer or if a trucking firm owns the trailer.

The Economic Issues

As mentioned above, this dissertation will undertake to examine the economic consequences of establishing transportation companies. The formation of a transportation company, resulting from combining two or more carriers of different modes, could involve economies from two sources. Common ownership could lead to economies of scale and potential economies involving the possible reallocation of traffic from high to low cost modes.

Economies of Scale

As alluded to in the arguments for and against establishing transportation companies, most, if not all economic arguments

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[4] Nicholas A. Glaskowsky, Jr., *An Analysis and Evaluation of the Development of Coordinated Air-Truck Transportation with Special Reference to [illegible] Air Lines, Inc.* (Unpublished Ph.D. dissertation, Graduate School, Stanford University, 1960), p. 10.

on the common ownership question, are centered on the question of the extent to which economies of scale can be obtained by the merger of two modes (rail and truck). Comments such as the following are typically made by transportation economists.

> The economies which may be realized from common ownership are dubious, to say the least, as is evident from the earlier analysis of economies of scale in the various modes of transport ... in addition ... the competitive nature of motor ... transport would make it impossible for them to absorb any significant amount of the railroad burden.[5]

From the positive side,

> In summary, ... integration can lead to economies in the use of administrative personnel, maintenance, personnel, labor of all kinds, equipment, and capital facilities. Many of these lead to better service through specialization of labor or capital and, at the same time, lead to greater profit for the firm.[6]

As can be seen, the disagreement centers on the question of how similar are the operating functions of the combining modes and is there enough similarity to allow the transportation company to centralize functions and eliminate duplicative functions, and so forth. These kinds of questions will be addressed in Chapter VI. As will be pointed out in Chapter VI, there really has not been enough research done in this area of the transportation company concept to answer the question of

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[5] Dudley F. Pegrum, Transportation Economics and Public Policy, Revised Edition (Homewood, Illinois: Richard D. Irwin, Inc., 1968), p. 463.

[6] Roy J. Sampson and Martin T. Farris, Domestic Transportation: Practice Theory, and Policy, (Boston, Mas.: Houghton-Mifflin Company, 1971), p. 326.

whether or not there are substantial economies of scale to be obtained from combining different modes. Therefore economies of scale will not be directly considered in this study. The effects of not directly considering economies of scale on the analysis of the results of this project will be explained in detail in Chapter V.

Economies Resulting from the Reallocation of Traffic

The major focus of this research project will be on the analysis of the potential economies of common ownership involving the possible reallocations of traffic from high to low cost modes. An explanation of why it may be possible for a transportation company to obtain economies from reallocating traffic from high to low cost modes deserves some attention.

Currently, carriers have the leeway to price services between out-of-pocket and fully distributed costs[7] under current regulatory policy.[8] Assuming firms are profit

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[7]Out-of-pocket costs is a term used in transportation referring to the added costs incurred in performing an additional service. Fully distributed costs are the total of variable costs and a prorated portion of applicable fixed costs including a profit allowance for a transportation movement.

[8]The Passage of the Transportation Act of 1958 added paragraph 3 to the Rule of Rate making (Section 15a) of the Interstate Commerce Act. In particular, the Congress declared that, "rates of a carrier shall not be held up to a particular level to protect the traffic of any other mode of transportation, giving due consideration to the objectives of the national transportation policy declared in this act.' In effect, this

maximizers for the most part and given there is excess capacity, it then follows that single modal carriers will carry traffic as long as it contributes something to margin. Because each mode has different cost characteristics (differing amounts of fixed and variable costs) and given that carriers are profit maximizers,[9] there exists in transportation today a situation

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addition to the I.C.A. directed the Interstate Commerce Commission (I.C.C.) to base rates for services provided by carriers on the basis of microeconomic analysis of the situation.

Prior to 1958, the I.C.C. dictated that rates should be no lower than necessary to afford the carriers a fair opportunity to compete. In determining if rates were just and reasonable, the Commission would consider such things as: (1) the effect a new rate would have on the traffic of another carrier, (2) the relation of the rate to those of other carriers, and (3) whether the rate was lower than necessary to meet the competition.

The test case for the 1958 Rule of Rate Making was the Sea-Land Case (I.C.C. v. New York, New Haven, and Hartford R.R. Co., 372 U.S. 744 (1963)) which went all the way to the Supreme Court for the final decision. The Supreme Court accepted fully distributed costs as a measure of inherent advantage as a test for determining whether a particular rate is unfair or destructive. The Court did, however, stipulate conditions when this finding could be overruled. These are: (1) when and if other acceptable costing standards were developed by the I.C.C., (2) a high cost carrier can base rates on out-of-pocket costs rather than fully distributed costs provided these are not below the fully distributed costs of the low cost carrier. Thus, the Sea-Land Case reaffirmed that the I.C.C. was to utilize microeconomic analysis in the determination of rates for single modal carriers in competition with carriers in other modes. The second exception made by the Court has created a great controversy which is still unsettled today (see Ingot Molds, Pa. to Steelton, Ky., 323 I.C.C. [illegible] (1965)) concerning the level of costs to employ when specific transport markets are subject to intermodal competition. At the present time, rate relationships between competing modes rest somewhere between a full cost and some version of marginal or out-of-pocket costs.

[9] To lend [illegible] validity to this assumption Sampson and Farris (op. cit., p. [illegible]) state that a main goal of carriers is to maximize profits.

where carriers of one mode are competing for traffic which can be moved more profitably at the same or competitive rates by carriers of another mode (with different cost characteristics). This point is substantiated by past chairman of the I.C.C. Howard Freas when he pointed out in 1958:

> However, when competitive traffic is hauled at a minimum of profit by carriers whose costs are relatively high, the low cost carrier who at the same or lower rates could provide the service at a reasonable profit is deprived of the business. By having the high cost carrier perform the service, the overall charges to the public are not reduced as other traffic must bear a disproportionate share of the total transportation burden. Thus, the public is prevented from receiving the benefit of the more economical service.[10]

Thus it is evident that there exists the potential for a transportation company to achieve economies by reallocating traffic from high to low cost modes. Whether this is possible or not depends on many factors which must be analyzed.

To date there has been no quantitative microeconomic analysis of the transportation company concept. Peter S. Douglas has supported this finding and states in a recent article, "No proponent of 'common ownership', however, has yet undertaken publicly to identify the economic forces that might make coordination of separate modes less costly under a single management than under separate managements."[11]

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[10] U.S. Congress, Senate Committee on Commerce, National Transportation Policy (The Doyle Report), S. Rept. 445, 87th Congress, 1st Session, 1961, p. 217.

[11] Peter S. Douglas, "The Economic Irrelevance of 'Common Ownership'," I.C.C. Practitioners Journal, XXVI (July-August, 1969), p. 1766.

Purpose of the Dissertation

In the light of the previous discussion on the economic issues of the common ownership controversy, the purpose of this dissertation may be stated. The purpose of this research project is to examine the economic impact various combinations of parameters or test factors have on a transportation company formed from single modal carriers. In the accomplishment of this goal, the research project will attempt to provide information on the cause and effect nature the parameters have on the economic performance of the transportation company as compared to the economic performance of the single modal carriers of which the transportation company is comprised. A secondary, but important, goal of the research is to provide a basis for future research efforts.

The Research Approach

The research approach used in this project will be to identify the exogeneous controllable and uncontrollable variables, the endogeneous variables, the constraints, and the relationships between them. Taking these factors into consideration, a mathematical simulation model will be constructed. Once the mathematical model has been developed, a hypothetical transportation system will be analyzed in which the parameters and constraints will be allowed to systematically vary to determine what effect each has on the solution of the model.

It should be pointed out that this type of an approach to the problem is necessary for the following reasons: (1) while it is not necessarily easy to abstract the real world into symbolic models, it is the only practical way in which the operations of an integrated transportation company can be compared with the operations of competitive single modal carriers made up of its composite companies. There is no data on which one can draw which compare the operations of a truly integrated transportation company with competitive single modal companies. That is, while there are some transportation companies in the United States, they do not compete directly with single modal carriers with exactly the same route structures, load factors, management skills, and so forth. (2) As one might guess, the carriers, shippers, and regulatory authorities as a group are not willing, for their own parochial reasons, to experiment with one segment of our transportation system to see if the concept really "holds water". Furthermore, even if one experiment did work, this fact would offer no proof that the concept would be valid under all conditions. Thus, one of the benefits of utilizing mathematical simulation models is that it is possible to manipulate the parameters involved which make two situations different to determine the outcome on the solution at a reasonable expense. (3) The formulation and use of a simulator to analyze this problem area has never been attempted before and hopefully this approach will be used as a building block to extend quantitative methods to aid carrier managements.

The data used in this study will be hypothetical yet will reflect actual differences in operating characteristics between modes. Realistic hypothetical data serve the purpose of this dissertation as well as real data, because they will be used as a common denominator for comparing the same transportation modes operating under different organizational structures.

With respect to simulation _per se_, it has been defined as follows:

> A simulation of a system or an organism is the operation of a model or simulator which is a representation of the system or organism. The model is amenable to manipulations which would be impossible, too expensive or impractical to perform on the entity it portrays. The operation of the model can be studied and, from it, properties concerning the behavior of the actual system or subsystem can be inferred.
>
> In essence, simulation can be viewed as an experimental means for generating an artificial history of a system for purposes of analysis.[12]

Thus one of the distinguishing characteristics of simulation studies is their reliance on the model-building approach to examine problems. Hillier and Lieberman have put forth this proposition as follows:

> ...simulation typically is nothing more or less than the technique of performing sampling experiments on the model or system. The experiments are done on the model rather than on the real system itself only because the latter would be too inconvenient, expensive, and time consuming. Otherwise, simulated experiments should be viewed as virtually indistinguishable from ordinary statistical experiments...[13]

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[12] Norman L. Chervany, _A Simulation Analysis of Cash Flow Patterns Within A Manufacturing Organization_, (Unpublished D.B.A. dissertation, Graduate School of Business, Indiana University, 1968), p. 10, quoting from Martin Shubik, "Simulation of the Firm", _American Economic Review_, L (December 1960), p. 909.

[13] Frederick S. Hillier and Gerald J. Lieberman, _Introduction to Operations Research_ (San Francisco, California: Holden-Day, Inc., 1967), p. 440.

It must be recognized, however, that while there are certain advantages in utilizing this model-building approach to analyze a problem area, there are corresponding disadvantages. As Hillier and Lieberman put it:

> Mathematical models have many advantages over a verbal description of the problem. One obvious advantage is that a mathematical model describes a problem much more concisely. This tends to make the over-all structure of the problem more comprehensible, and it helps to reveal important cause-and-effect relationships. It also facilitates dealing with the problem in its entirety and considering all of its inter-relationships simultaneously. ...
>
> On the other hand, there are pitfalls to be avoided when using mathematical models. Such a model is necessarily an abstract idealization of the problem, and approximations and simplifying assumptions generally are required if the model is to be tractable. Therefore, care must be taken to insure that the model remains a valid representation of the problem.[14]

With these advantages and disadvantages in mind this model-building approach will be utilized to achieve the objectives of this dissertation. The study will be undertaken in three distinct phases. First, the model used to analyze the economic consequences of establishing transportation companies will be presented. Secondly, the test factors and performance measures utilized in the study will be presented. In this phase of the study, the relationship of the model to the real world will be critically discussed. Thirdly, the evaluation of the results of the simulation will be presented as well as the implications the study has on the real world and future research.

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[14] Ibid., p. 15.

Contribution of the Dissertation

Speculation and intuitive belief have guided the arguments concerning the establishment or formation of transportation companies. Investigation, not speculation, is required if objective decision criteria are to be established, as to when or under what circumstances transportation companies would be in the public interest. As indicated above, developing criteria for this purpose is a multi-dimensional undertaking. This dissertation is concerned with one part of the economic feasibility of common ownership. The dissertation will answer such questions as under what operating conditions, traffic conditions, and cost conditions will the transportation company result in lower costs for transportation users and/or greater profits[15] for the industry than by keeping the individual modes separate.

The results and methodology of this study could hopefully be incorporated in a rigorous systems analysis of the concept which should be performed by the I.C.C. or Department of Transportation. The major thrust of the research could then be thought of as a necessary part of a systems analysis on the common ownership controversy which identifies some of the economic impacts on the carriers involved in forming transportation companies. The information

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[15]Profitability will be measured in terms of the total contribution made to fixed and/or common costs including profit margin. For a detailed explanation of why this measurement was used see Infra, chapter V, pp. 160-162.

generated and methodology used in this dissertation could be incorporated as part of the analysis necessary to determine if such companies would be in the public interest. The I.C.C., if it were to attempt such an analysis, would also have to consider not only the economic aspects of the problem, but also such factors as to how such companies would affect shipper convenience and service, effect on carrier employees, legality, desired levels of competition, regulatory problems, and whether or not such companies could be effectively organized and managed. Only after all these questions have been researched can appropriate decision criteria be formulated as to when the formation of a transportation company would be socially desirable.

The major focus of this research will hopefully provide a new perspective and a foundation for research on the question of the transportation company concept. The research should, however, provide guidelines as to under what circumstances a transportation company will be more profitable than single modal competing carriers.

The methodology utilized in this study could also be used, as a foundation, to develop a rational basis for determining when carriers should provide coordinated or single modal transportation services.

Finally it is hoped that this dissertation will be used as a building block to extend the applications of quantitative methods in carrier management.

Organization of the Dissertation

The remainder of this dissertation consists of six chapters. Chapter II involves the formulation of the model. The chapter deals with the definition of the relevant decision variables, explanation of the form of the objective functions, and statement of the set of constraints within which the simulation will operate. The chapter also presents a discussion of the scope of the research as well as a description of the pertinent assumptions.

The first part of Chapter III identifies the parameters as well as the random components of the model which will be varied in the analysis of the model to determine what effect each has on the solution of the model. The remainder of the third chapter explains how the cost data will be generated. The costing categories for the modes are established and an explanation of the manner in which the test factors effect costs is given. Following this explanation, the transportation system which was modeled is presented.

Chapter IV focuses attention on the nature of the experimental design and the analytical and statistical methodology used in the dissertation. The chapter discusses the problem of realism in the simulation and presents the performance measures or summary statistics which are used to describe the results of the simulation. The chapter also discusses the nature of the particular experimental design utilized in the study.

The fifth chapter presents and analyzes the results of the simulation. The analysis indicates which test factors significantly affect the economic impact of a transportation company vis-à-vis single modal carriers.

Chapter VI identifies the other aspects of the common ownership controversy that were not considered in this project and discusses their relationship to the research accomplished in this study.

Chapter VII discusses the results and implications of the study in the broader framework of the controversy.

CHAPTER II

DEVELOPMENT OF THE MODEL

Very broadly stated, the purpose of this chapter is to: (1) develop the foundation for the simulation model utilized in this project; and (2) present and discuss the simulation model. The chapter begins by identifying the scope of this research effort. Next the important assumptions which are made during the conduct of the research are discussed. Following this discussion, the key variables of the simulation model are presented with the purpose of introducing the model in an overview fashion.

The chapter will then present a description, in mathematical and verbal terms, of the nature of the decision environment within which the shippers and carriers operate. Attention will be given to the interactive nature of the process by which carriers make equipment allocation decisions and shippers choose methods of transportation for movements. The nature of the manner in which carriers determine rates is then presented. The simulation model which will be used for analysis in the project is then presented and described.

Scope of the Research

The American transportation system, which is concerned with the movement of freight, is so pervasive that it is almost beyond imagination. The system is composed of thousands of origins and destinations connected by millions of miles of roads, railroad tracks, canals, rivers, pipelines, and air routes. There are five modes of transportation concerned with the movement of freight. These modes involve motor, rail, water, pipeline, and air transportation. These modes literally move billions of ton-miles of freight each year.

To simplify the analysis and to limit the scope of the research to a manageable size, the research will restrict the number of origins and destinations, the number of founding modes, and the number of commodities considered.

Because there are many possible combinations of modes which could be formed into a transportation company, the research will consider the two modal corbination which would most probably have the most significant economic impact on both the shippers and carriers concerned. Air carriers and freight forwarders are involved with a relatively minor amount of the total freight movements. Domestic water carriers are limited to their geographically controlled route structures. Pipelines carry a very limited product line. The analysis will therefore limit the system considered to the two modal case involving a railroad and a trucking company, and a transportation company which operates both the rail and highway modes. These two modes are by far the most important modes involved in the movement of freight.[1]

In simplifying the analysis by considering only two modes, the results which will be obtained are restricted to the modes considered. This is so because each mode has different economic or cost characteristics which must be considered in the research. The extension of the analysis to transportation companies consisting of more than two modes is conceptually straight forward, although not necessarily easy to accomplish. To consider other two modal transportation companies composed of different modes should be a simple process once the methodology is established.

This study will address itself to only a portion of the total rail-truck market. The study will focus attention on common carrier truck and rail movements including Plan I and Plan II piggyback movements. Other forms of piggyback movements will not be considered.[2] Furthermore, the analysis will also consider only one product. This product may be considered to be the class of commodities which are subject to intermodal competition for movement.

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[1]In 1969 the total estimated revenue of all regulated freight carriers was approximately 26.4 billion dollars. Of this total regulated railroads and motor carriers accounted for 92.05% of this total or 24.3 billion dollars. "American Trucking Trends 1970-71", Departments of Research and Transport Economics and Public Relations, American Trucking Associations, Inc. (Washington, D.C.), p. 16.

[2]Plan I piggyback movements utilize common carrier truck trailers on rail owned flatcars. Plan II piggyback movements involve rail owned trailers and flatcars. There are other forms of piggyback movements which involve shipper owned truck trailers, and still others which cater to freight forwarders.

Restricting the analysis to one product with average commodity characteristics does present some difficulties. The commodity characteristics of goods does affect the cost of movement. Once a system is solved for the average commodity, it may prove worthwhile to adjust the costs in the analysis by the amount these characteristics cause the costs to deviate from the average. If this is done, the transportation firms would have exact commodity break points for the modes over a certain segment.

The size of the transportation market which is subject to the intermodal competition is an important factor for determining if a transportation company has a greater profit potential than two single modal carriers. If all traffic were subject to intermodal competition, there could exist many possibilities where a transportation company could generate a greater profit contribution than the competitive single modal carrier by allowing each mode to be used in its most profitable market segments. If there were no traffic subject to intermodal competition, there would be no increased profit potential for a transportation company by allocating each mode to its proper economic role. There may however still be some economies of scale involved in this situation.

To the extent that service differs between the modes, the effective size of the amount of traffic which is subject to intermodal competition is reduced. For instance, if speed between modes were substantially different between two points and this was an important decision variable for a shipper, this factor would reduce the amount of traffic subject to intermodal competition. The effect this would have would be to reduce the area in which effective savings are likely to result by the reallocation of traffic to the most profitable modes. This type of situation could result also if a shipper's logistics system was set up only for one mode of transportation, regardless of whether or not it is the low cost carrier by which the transportation company would like to move his shipments. To the extent this type of situation prevents the movement of goods by the low cost carrier, the less will be the economic impact created by forming transportation companies. These types of situations can be incorporated into the analysis by constraining the manner in which movements can be made between origins and destinations.

Restricting the number of origin and destination pairs to that which is manageable does not really affect the generality of the results. For instance once the break points where modal shifts should occur are found on a particular network segment, all the origin and destination pairs between those points should be served by the same modes or modal combinations.

One further limitation will be placed on the analysis performed in this dissertation. The simulation will be a short-run economic analysis. In fact, the simulation runs which will be analyzed will be concerned with comparing the economic performance of a transportation company with a single modal railroad and trucking company for a single time period. This time period may be thought of as being one day. The analysis will not suffer due to this limitation because, as will be shown in a later section of this chapter, the decision processes which are being simulated remain the same from time period to time period.

Assumptions

Now that the scope of the research has been described, this section will identify the pertinent assumptions which will be utilized in the formulation of the simulation model.

The study will assume that the appropriate regulatory agency, the Interstate Commerce Commission, will continue to safeguard the public interest. In other words, it will be assumed that the activities of a transportation company, as well as the single modal carriers, will not be allowed to run contrary to the public interest by such actions as charging exhorbitant rates or discrimination between shippers. This assumption of continued regulatory supervision allows the author to assume that the rates charged by the single modal carriers and the transportation company will be determined by a consistent policy which will be explained in a later section. Furthermore, it will be assumed that the I.C.C. through its rate making policy will control the average operating ratios of the modes. The I.C.C. will thus indirectly control the average rate of return for the modes.

Since the time frame necessary for the analysis is a short-run analysis, one can assume that the physical plant of the companies is fixed. That is, the number of tractors, trailers, flatcars, locomotives, terminals, line miles of track, road miles, and so forth, will be considered as constants in the analysis. Furthermore, the technological state will be limited to the current state of the art.

For certain movements, the physical characteristics of products restrict certain modes from carrying them. For instance, the shock resistance, or size or weight of some commodities could limit them from being moved by any one mode. This factor reduces the number of combinations of coordinated movements to those involving the modes which are physically capable of carrying the goods. The model developed below will consider the commodity to be capable of being transported in a standard railroad boxcar and/or a standard truck trailer. Piggyback movements will be limited to the standard configuration of one or two standard truck trailers on a flatcar.

In addition the assumption will be made that <u>when</u> the service characteristics of the modes are equal, shippers have no real preference between the modes if they are physically capable of dealing with each mode.

It will also be assumed that shipments subject to logistics constraints will be moved before the carriers move competitive traffic. This seems reasonable because carriers might be expected to satisfy a guaranteed market before they would enter into the competitive market place.

Furthermore it will be assumed that the transportation company faces the same demand pattern as the two single modal companies of which it is composed.

The final assumption which will be made in this project is that the transportation company can be effectively organized in such a manner as to achieve its objectives. The objective functions of the transportation company and the single modal carriers will be presented in this chapter.

The assumptions utilized in this study will be critically analyzed throughout this thesis to determine the impact they have on relating the results of this study to the real world. In addition, Chapter VI devotes special attention to the discussion of these assumptions and their relationship to the real world.

Identification of the Important Variables

Now that the pertinent assumptions which will be utilized in the formulation of the model have been stated, this section will identify the important variables with which the model will be concerned. The purpose of this section is to acquaint the reader, on a very general basis, with the "input and output" variables used in the simulation analysis. This material is presented at this time to facilitate the understanding of the mathematical structure of the decision environment and the simulation model which will be presented in the next two sections of this chapter.

There are two classes of variables which the models, to be developed in the next section, manipulate to arrive at a solution. These variables are exogenous and endogenous variables. "Exogenous variables are the independent or input variables of the model and are assumed to have been predetermined and given independently of the system modeled."[3] Exogenous variables may be subdivided into controllable and uncontrollable variables. "Endogenous variables are the dependent or output variables of the system and are generated from the interaction of the systems (model's) operating characteristics."[4] Endogenous variables are synonomous with the decision variables in this study. The parameters in the models formulated below may be thought of as specific values of the exogenous variables. In other words, the models will be solved with different parametric values. These parametric values may be thought of as "snapshots" or a specific value of an exogenous variable.

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[3]Thomas H. Naylor, Joseph L. Balintfy, Donald S. Burdick, Kong Chu, Computer Simulation Techniques, (New York: John Wiley & Sons, Inc., 1967), p. 10.

[4]Ibid., p. 11.

Exogenous Variables

Attention will be focused first on the exogenous variables and in particular on the uncontrollable exogenous variables. The cost of movement between any two given points may be considered an exogenous uncontrollable variable which is a function of many other uncontrollable variables.

There are many variables which affect the cost of movement. These variables may be divided into two categories--those which are concerned with the characteristics of the commodity being moved and those which are concerned with the route over which the movement will take place. The following commodity characteristics all have an effect on the cost associated with the movement of a particular commodity: loading characteristics, susceptibility to loss and damage, volume of traffic, regularity of traffic, and the nature of equipment required. The following route characteristics also directly affect the cost of movement: distance, operating conditions such as geographical and weather factors, and traffic density.[5]

Another exogenous, uncontrollable variable is the demand for transportation between points. While it may be true that individual carriers can affect the demand for their services over

[5] See for instance, Germane, Glaskowsky and Heskett, op.cit., Chapter 4.

time, the short-run nature of the study has the effect of fixing the demand for the carriers involved. The same is true for the amount of traffic which must be allocated to one mode or the other due to shippers' logistics constraints.

It should be pointed out that the nature of this analysis, being a (very) short-run economic analysis, has the effect of adding certain variables to the list of uncontrollable exogenous variables which over a longer time period would be controllable variables. The short-run analysis also has the effect of more or less "fixing" these variables at the values they have assumed at the "moment" of observation.

The controllable exogenous variable in the analysis is the schedule of carrier operations. This variable is a function of both cost and demand. For instance, rail management may institute a policy of moving freight only when the train reached 100 cars (approximately). This may have the effect of limiting service for a certain community to once-per-day service. In essence the scheduling activities of the carriers create the amount of capacity which is available at each point for movements, although total capacity is fixed.

Endogenous Variables

The models for the single modal companies and the transportation company which will be presented in the next section, produce a number of endogenous or decision variables. These variables are the amount of hundred weight (Cwt.) that will be moved between origins and destinations by truck, rail, or piggyback, and the amount of capacity the carriers will allocate to the various origins. The rate at which carriers price their services to shippers is also an endogenous variable, although the levels rates can assume are bounded by regulatory restrictions as will be explained in the next section.

The rate shippers are charged is dependent upon the cost functions of the carriers. The rate between two points is dependent not only upon the commodity and route characteristics of the movement but is also dependent upon the competitive nature of the movement. As will be discussed below, carriers have a certain amount of leeway in pricing their services when confronted with competition.

The amount of Cwt. moved between origins and destinations by each of the methods of movement is dependent upon: (1) the demand for transportation; (2) the amount of traffic which is constrained to move by each mode due to shippers' logistics constraints; (3) the amount of capacity carriers allocate to each origin; (4) and the manner in which shippers select the modes for traffic which is not constrained, i.e., competitive traffic.

The equipment allocation decisions of the carriers is dependent upon the amount of contribution to fixed and/or common costs including profit allowance each movement makes. That is the carriers will allocate their equipment in such a manner as to maximize their expected contribution. The expected contribution is dependent upon: (1) the forecasted demand between origin and destination pairs; (2) the cost characteristics of the movements; (3) the amount of traffic constrained for each mode by shippers' logistics systems; and (4) the competitive nature of the movements.

The Decision Environment

From the discussion in the preceding section it is apparent that the decision process of the carriers and shippers are interactive to a large degree. The nature of this decision environment will be explained in detail in this section.

The decision environment within which the shippers and carriers operate can be viewed as a constrained minimization problem which interacts with a constrained maximization problem. In other words, shippers will choose the least cost, as measured by rate, method of movement between two points given that this method does not violate the shippers' logistics constraints. Operating within this decision framework, the carriers will attempt to maximize their contribution to fixed and/or common costs including profit margin by allocating their equipment to the most "profitable" route segments. The amount of capacity available to shippers at each origin then is dependent upon the equipment allocation decisions of the carriers.

Identification of the Symbolic Terminology

The nature of these interactive decision processes will be examined in detail following the identification of the necessary symbolic terminology.

Let X_{ijk} be the number of hundred weight (Cwt.) moved from point j to point k by mode i. The designator i equals 1 when the movement is by common carrier truck, 2 when the movement is by Plan I piggyback, 3 when the movement is by Plan II piggyback, and 4 when the movement is by rail. The designator j represents origins; k destinations. Thus the variable X_{1AB} would indicate the number of Cwt. moved from A to B by truck. In other words, the X_{ijk} are the decision variables which in the solution will indicate how much product will be moved by what modes between given points to satisfy demand.

Let r_{ijk} be the rate per Cwt. charged by a carrier for moving the product between j and k by mode i. Similarly, let C_{ijk} be the out-of-pocket cost[6] to the carrier for moving the product between j and k by mode i. The i's, j's, and k's are defined as above.

Let d_{jk} represent the demand in Cwt. for transportation service between the two points j and k.

Y_{ijk} is the capacity in Cwt. allocated by mode i for movements between j and k. Y_{1jk} and Y_{2jk} is the amount of single

[6] Supra, chapter i, p. 7.

modal trucking capacity available for over-the-road and Plan I piggyback movements, respectively. Y_{3jk} is the amount of rail owned trucking capacity available for Plan II piggyback movements. Y_{4jk} is the amount of rail capacity allocated for movements between j and k. F_R is the amount of flatcar capacity which the railroad has available for both types of piggyback movements. F_T the amount available for Plan I moves is equal to $F_R - \sum_{j}\sum_{k} Y_{3jk}$. That is, the railroad does not have to provide flatcars for Plan I moves. The railroad will only do so if it is not using all flatcar capacity for Plan II. F_R and F_T will also be expressed in Cwt. capacity available by multiplying the number of flatcars available by the capacity of two standard truck trailers.

W_{jk} will be the amount of traffic which must be loaded into truck trailers, either rail or truck company trailers, at j movement to k. This is the quantity of product for which shippers' logistics systems are set up for trucking operations only. In other words, some shippers only have terminal facilities for truck trailers. Similarly U_{jk} is the amount of Cwt. which must be shiped by rail due to some shippers' logistics constraints, between j and k.

Z_{jk} is the amount of product which must be moved between points j and k by the truck over-the-road. This quantity may be thought of as the amount of traffic which must be moved faster than what the rail or piggyback modes can offer. Again this is a logistical constraint of the shippers which must be satisfied.

The Shippers' Dilemma

The nature of the problem which shippers face, that of choosing a method of movement, is a constrained minimization problem which fits within the framework of linear programming. In other words, after the carriers have made their equipment allocation decisions, the shippers must choose how to move their products. The linear programming formulation for the shippers' selection among alternative modes when faced with a system of single modal carriers is presented below.

Shippers' Modal Selection Model
When Faced With Single Modal Carriers

$$\text{Min } Z = \sum_{jk}\sum [r_{1jk}X_{1jk} + r_{2jk}X_{2jk} + r_{3jk}X_{3jk} + r_{4jk}X_{4jk}]$$

Subject to:

Demand satisfaction

$$(1)\quad X_{1jk} + X_{2jk} + X_{3jk} + X_{4jk} = d_{jk} \text{ for all } j \text{ and } k$$

Capacity constraints

$$(2)\quad X_{1jk} + X_{2jk} \leq Y_{1jk} + Y_{2jk} \text{ for all } j \text{ and } k$$

$$(3)\quad \sum_{jk}\sum X_{3jk} \leq F_R$$

$$(4)\quad \sum_{jk}\sum X_{2jk} \leq F_R - \sum_{jk}\sum X_{3jk}$$

$$(5)\quad X_{3jk} \leq Y_{3jk} \text{ for all } j \text{ and } k$$

$$(6)\quad X_{4jk} \leq Y_{4jk} \text{ for all } j \text{ and } k$$

Logistics systems constraints

(7) $X_{1jk} + X_{2jk} + X_{3jk} \geq W_{jk}$ for all j and k

(8) $X_{4jk} \geq U_{jk}$ for all j and k

(9) $X_{1jk} \geq Z_{jk}$ for all j and k

$$X_{ijk} \geq 0$$

The different modes of transportation have different cost characteristics which are reflected in rates in the objective function. Faced with these sets of rates, shippers will allocate their traffic to the low cost mode, given that their logistics system does not constrain their choice.

The demand satisfaction constraints--equation (1)--insure that demand is met providing the carriers have provided adequate transport capacity at the various points--equations (2), (3), (4), (5) and (6). If the carriers do not provide enough capacity at each origin, there may be no feasible solution to the above problem. In other words, the demand for total transportation services may not be satisfied between all origins and destinations, if the carriers do not allocate their equipment in such a manner to make demand satisfaction possible. The manner in which carriers make their equipment allocation decisions will be discussed in the following section of this chapter.

Equations (7), (8) and (9) constrain the solution to be compatible with logistics systems of the shippers. Equation (7) indicates that certain shippers have logistics systems which are capable of handling only truck trailers, although a decision must be made as to how to move the goods--by truck, Plan I or Plan II piggyback. Equation (9) indicates some shippers must have their product moved by truck for speed of delivery. Equation (8) indicates some product must be moved in rail boxcars again because of shipper logistics systems demands.

Similarly, the linear programming formulation for the shippers' selection among alternative modes when faced with a transportation company consisting of the same two modes is presented below.

Shippers' Modal Selection Model When
Faced With Transportation Company

$$\text{Min } Z = \sum_{jk}\sum [r_{1jk}X_{1jk} + r_{3jk}X_{3jk} + r_{4jk}X_{4jk}]$$

Subject to:

Demand satisfaction

(1) $$X_{1jk} + X_{3jk} + X_{4jk} = d_{jk} \text{ for all } j \text{ and } k$$

Capacity constraints

(2) $$X_{1jk} + X_{3jk} \leq Y_{1jk} + Y_{3jk} \text{ for all } j \text{ and } k$$

(3) $$\sum_{jk}\sum X_{3jk} \leq F$$

(4) $$X_{4jk} \leq Y_{4jk} \text{ for all } j \text{ and } k$$

Logistics systems constraints

(5) $X_{1jk} + X_{3jk} \geq W_{jk}$ for all j and k

(6) $X_{4jk} \geq U_{jk}$ for all j and k

(7) $X_{1jk} \geq Z_{jk}$ for all j and k

$$X_{ijk} > 0$$

This formulation is very similar to that of the two modal competitive model. One major difference, however, is that the set of decision variables X_{2jk} and Y_{2jk} are absent in the model. This arises because the transportation company owns both modes so that Plan I piggyback is identical to Plan II piggyback. Perhaps a new notation could be developed for this type of piggyback movement, but to keep the interpretation of symbols as easy as possible X_{3jk} will be used to indicate a piggyback movement by the transportation company.

Equations (1), (2), (3) and (4) serve the same purpose as in the single modal competitive model, that is to insure that demand is satisfied if there is adequate capacity available. Equations (5), (6) and (7) constrains the solution to be compatible with shippers' logistics demands.

These linear programs because of their structure have trivial solutions. The solutions to the programs will always involve shippers' choosing the low cost mode of transportation given this is not incompatible with their respective logistics systems and providing that carriers' allocate their equipment in such a manner that this is possible. This fact will simplify the formulation of the simulation model.

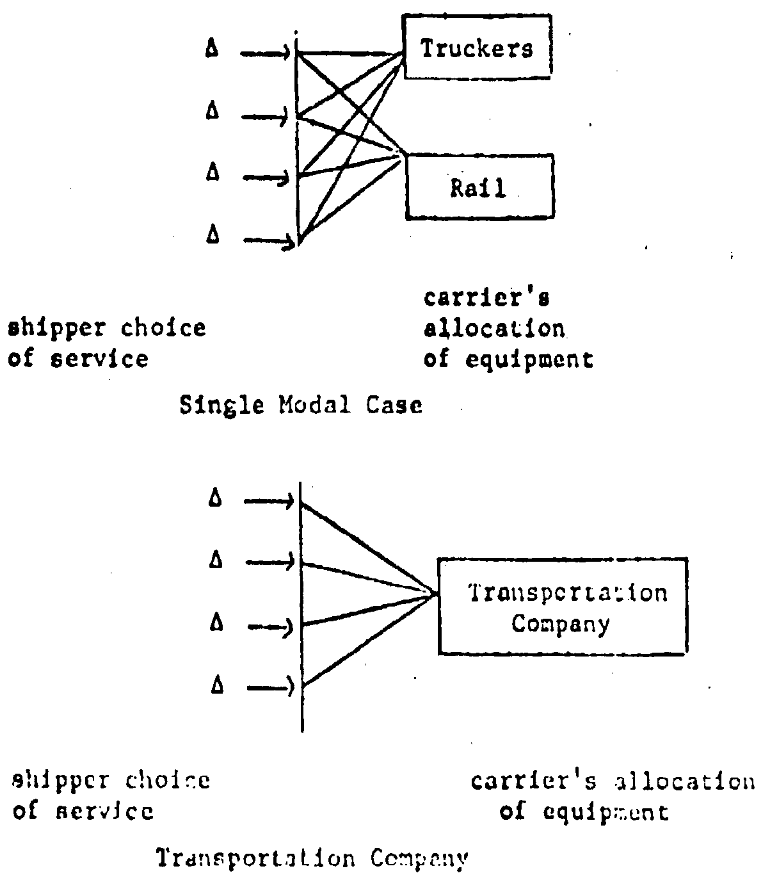
The Carriers' Equipment Allocation Dilemma

The above discussion of the shippers' dilemma is but one part of the total decision environment in which the carriers and shippers operate. This section will focus attention on the nature of the problem the carriers face.

If a transportation company is to create any economic benefits, it must be able to offer transportation services at the same or lower rate to shippers while maintaining or improving upon the profitability which single modal firms could obtain. As mentioned previously, this would be possible if the transportation company could achieve economies of scale and/or if the allocation of equipment by the transportation company results in greater total profits than the manner in which the single modal companies allocate their equipment.

If the allocation of equipment to origins is different between the two organizational forms, i.e., single modal carriers vis-à-vis a transportation company, this will have an effect on the profitability of the two forms as well as on the price paid for transportation services by users. In the single modal situation the trucker and the railroad both make independent equipment allocation decisions. The trucker decides how much trucking capacity to allocate each origin for trucking movements and Plan I piggyback movements. Similarly, the railroad independently decides the amount of boxcar, rail owned truck trailers, and flatcar capacity to allocate to each origin. The transportation company, on the other hand, makes capacity allocations as a single "profit center" which may result in different capacity allocations to the origins than those that the single modal carriers make. This situation is displayed graphically in Figure 1.

Figure 1. Structure of Equipment Allocation Decisions



The allocation of equipment to specific origins by the carriers determines the amount of capacity available to shippers at each origin. In other words, the solution of the above problem places the capacity constraints, Y_{1jk}, F_T and F_R in the cost minimization linear program of the shippers. Operating within the framework where shippers are trying to minimize their transportation costs, the carriers wish to maximize their expected contributions to fixed and/or common costs and profit margin by the determination of price and the allocation of equipment.

Mathematically, the trucker wishes to maximize

$$\sum_{j}\sum_{k}[(r_{1jk} - C_{1jk})Y_{1jk} + (r'_{2jk} - C'_{2jk})Y_{2jk}]$$

where Y_{1jk}, Y_{2jk}, r_{1jk}, and C_{1jk} are defined above. The Plan I piggyback movements are coordinated movements which necessitates the sharing or splitting of the contributions to fixed and/or common costs and profit margin between the two firms. This contribution would have to be split between the firms on the basis of the cost contribution made by each firm.

$(r'_{2jk} - C'_{2jk})Y_{2jk}$ represents the truckers share of the expected contribution.

Similarly, the railroad wishes to maximize

$$\sum_{j}\sum_{k}[(r''_{2jk} - C''_{2jk})Y_{2jk} + (r_{3jk} - C_{3jk})Y_{3jk} + (r_{4jk} - C_{4jk})Y_{4jk}].$$

$(r''_{2jk} - C''_{2jk})Y_{2jk}$ is the railroad share of expected contribution resulting from Plan I piggyback movements. $(r_{3jk} - C_{3jk})Y_{3jk}$ and $(r_{4jk} - C_{4jk})Y_{4jk}$ are the rail expected contributions from Plan II piggyback and boxcar movements.

Operating within the framework of the second linear program, the transportation company also wishes to maximize the contribution to fixed and/or common costs and profit margin. Mathematically, the transportation company wishes to maximize

$$\sum_{ijk}\sum\sum(r_{ijk} - C_{ijk})Y_{ijk}$$

To accomplish these objectives the carriers must determine where to allocate their equipment. The carriers are constrained by the total amount of equipment (capacity) they own and by the logistics constraints of the shippers. Concommitant with their resource allocation decisions the carriers must also determine what rate they should charge shippers to use their services.

The Carriers' Pricing Dilemma

This section will outline the nature of the carrier pricing dilemma and indicate what leeway carriers have in pricing their services.

In general, because the two modes have different cost characteristics, i.e., before differing amounts of fixed and variable costs, the out-of-pocket costs and fully distributed costs for the modes will differ for a given origin and destination pair.[7] Because

[7] A full explanation of the differences in the cost characteristics of the truck and rail modes will be presented in Chapter III (*Infra*, p. 63). The discussion includes a description of the parameters which affect the cost of movement.

the costs of the modes will, in general, be different for the movement of the average product between two points, one needs a pricing or rate making scheme to determine the price of transportation services between various points. To be consistent with current transportation policy in this matter,[8] the following price setting mechanism will be utilized.

When the out-of-pocket costs of the high cost carrier are less than the full costs of the low cost carrier, the full costs of the low cost carrier will be the allowable floor for the rate. This statement is illustrated in Figure 2(a). In other words, the high cost carrier may, if he wishes, price his service at the full costs of the low cost carrier but no lower.

The high cost carrier may also price his services at his full costs. It may appear that there is no choice for the high cost carrier but to price his services at the level of the full costs of the low cost carrier. This is not the case however. Between any two given points the high cost carrier may have sold his services to some shippers on the basis of lower total logistics costs for the shippers even though their transportation costs may be higher than need be the case. In other words, transportation costs are but one of the costs involved in accomplishing the logistics function. Some shippers may elect for instance to trade-off higher transportation costs for lower inventory costs, and so forth. In the models developed in the

[8] Supra, chapter 1, p. 7.

previous section, these situations were incorporated in the logistics constraints which force a certain amount of traffic to move by some modes regardless of which is the low cost mode.

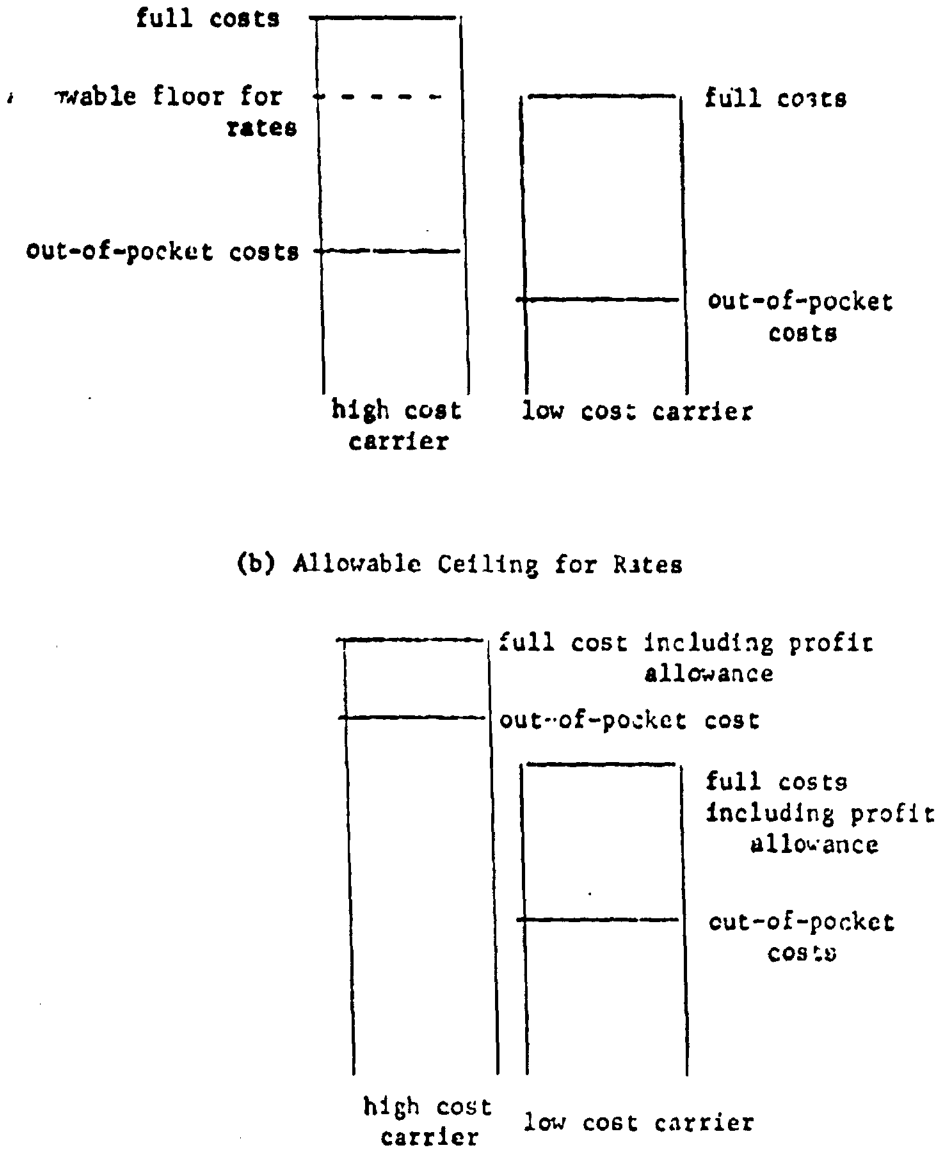
In light of this, the high cost carrier will price his services at either his full costs or at the low cost carriers' full costs depending upon which price contributes the most to profit. If services are priced at the same level the traffic between those points will be arbitrarily split equally between the modes. The high cost carrier will then examine how much traffic the logistics constraint requires be moved by his mode and the amount he estimates he could obtain by pricing at the low cost carrier's full costs. The high cost carrier will then determine under which price his contribution to profit and fixed costs will be largest and will accordingly price his services at that rate.

When the out-of-pocket costs of the high cost carrier between two points, is greater than the full costs of the low cost carrier, as depicted in Figure 2(b) the full costs of the respective modes will serve as their rates between two points. This is so because it has been assumed that the I.C.C. will allow a specific rate of return on each movement between all points.[9] The I.C.C. would

[9] In practice, the I.C.C. does not attempt to control the rate of return on each commodity between every origin and destination. The I.C.C. does attempt to control the rate-of-return for carriers in the aggregate, considering all movements of all commodities.

Figure 2. Restrictions on Carrier Pricing Decisions

(a) Allowable Floor for Rates



control the rate of return by specifying or controlling the average operating ratios of the modes.

The Simulation Model

The economic evaluation of a transportation company versus an independent trucker and railroad which will be undertaken in this study is based upon the simulation of the interactive decision environment just described. In the preceding sections of this chapter, all of the components needed to "construct" the simulation model have been presented. This section will bring the component parts of the simulator together and explain how the simulation was undertaken.

The simulator of the single modal carriers and the transportation company which was developed indicates how the firms should price their service and how they should allocate their equipment based on the criterion that each firm wishes to maximize its contribution to fixed and/or common costs including a profit margin. Solutions of the simulation model were generated for differing levels of the parameters which will be described in Chapter III. The solutions to the simulator may be thought of as a sensitivity analysis on the cost coefficients in the objective functions of the carriers, the level of logistics constraints, and on carrier capacity. More detail on the type of analysis that was performed is also presented in Chapter III.

This approach requires that the carriers know the full costs (rate) of the low cost mode and their own respective costs. This is reasonable in that the rate of the low cost carrier will be published in accordance with I.C.C. procedures. The approach also requires that each mode knows how much traffic is committed to each mode for movement due to shippers' logistics constraints and alternatively how much traffic in each route segment is subject to intermodal competition. This is not unreasonable providing the carriers have alert marketing research departments.

The same simulator can be utilized to determine the equipment allocation and pricing decisions of both the single modal carriers and the transportation company. The manner in which the algorithm is applied varies slightly for the two organizational approaches, however as will be explained. To determine equipment allocation and pricing decisions of the single modal carriers, the algorithm is first solved for a given set of parameters for the rail mode then proceeds to the trucking mode.

The simulator will now be explained in detail. The independent railroad first determines the full costs of making rail boxcar, Plan I, and Plan II piggyback movements for each route segment in the transportation system. The rail carrier then examines each route segment to determine if one of the methods of movement he controls (rail, Plan I or II) is the low cost method on each segment. For those route segments where he does not control the low cost method, he determines if he can price the services of one of his methods at the full cost of the trucker.

Once the railroad determines where he can compete for unconstrained or competitive traffic, he estimates how much of that market he can expect to obtain. Using these predictions, he determines which method of movement makes the greatest contribution for each route segment. In other words, on the segments where he has the low cost mode, say boxcar, he would compare the estimated contribution of his other methods priced at the boxcar rate and determine which method made the greatest contribution.

Once the estimated contributions for each route segment have been completed, the railroad ranks the expected contributions. This ranking determines the most profitable manner of pricing and equipment allocation for the carrier. The carrier will allocate his equipment beginning with the most profitable expected contribution and proceed to allocate his equipment down the rank until his capacity is exhausted. It should be remembered at this point that it has been assumed that shipments subject to logistics constraints will be satisfied first.

Since the algorithm was accomplished for the rail carrier first, the routine will now be run for the trucker, for a compatible set of parameters. Before the trucking routine is accomplished, however, the amount of flatcar capacity the railroad will offer to the trucker must be determined. If the rail carrier has used all its flatcar capacity, the trucker will be pre-empted from participating in Plan I moves. If the rail carrier has some flatcar capacity left, this amount will be made available for the trucker in case he should find it desirable to use Plan I piggyback movements. The simulation of the truckers decisions are analogous to these of the railroad and therefore need not be repeated.

The algorithm for the transportation company differs slightly from the one presented for the single modal carriers. First, the transportation company would not have to estimate how much of the competitive market it could obtain for each method of movement. The company would only have to estimate the total size of the market, as do the single modal carriers, but would then determine how to most "profitably" move that traffic since it controls all methods of movement. Also the additional bookkeeping of determining how much flatcar capacity is available for Plan I piggyback moves is eliminated.

This section does not complete the discussion on the simulation model. In fact this section has presented just the skeletal framework of the simulator upon which the following two chapters will expand. Chapter III presents a detailed discussion which focuses on the test factors which will be analyzed and describes how the cost data was generated. Chapter IV describes the performance measures used to evaluate the output of the simulation and discusses the nature of the experimental design utilized in the study. It is only after these chapters have been read that the reader will have a full understanding of the nature of the simulator utilized in this project.

CHAPTER III

SPECIFICATION OF THE MODEL

The preceding chapter presented and described the nature of the simulation model which will be utilized to determine the effects selected test factors have on the economic performance of a transportation company in contrast with that of two single modal carriers. The description of the simulation model was very general in nature, however. The parameters which the model manipulates to arrive at a solution were identified but only in an overview fashion.

The purpose of this chapter is fourfold. First, the chapter will focus attention upon the specification of the test factors selected for analysis and will explain how these factors effect the parametric values in the simulator. The discussion of this portion of the chapter will include the reasoning behind the selection of the test factors as well as the identification of the specific values of the factors. The second objective of this chapter is to identify the other specifics of the model. In this section of the chapter the random components of the model will be specified and the values of these random variables will be identified. This section will also describe the shippers' modal selection policy that will be used by the shippers in the model. Thirdly, the manner in which the costing data will be generated for use in the simulation model will be identified. The test factors which affect the cost of movement will also be identified, and the nature of the functional relationship between cost of movement and test factor values will be explained. Finally, the transportation system which was modeled will be presented.

Classification of the Test Factors

The parameters which affect a carrier's economic posture may be classified as environmental, commodity, and route factors. There are many environmental factors which could affect the economic well being of a carrier. For the purpose of discussion, the environmental factors may be divided into two groups--managerial and geographical factors.

Managerial factors, such as the competence of personnel, organizational effectiveness, and management-labor relations, are concerned with the managerial effectiveness of a carrier. These environmental factors will not be directly considered in the analysis because the transportation company and the single modal carriers which will be compared have been assumed to be able to achieve their objectives of maximizing their respective contributions to fixed and/or common costs including profit margin. Thus the competence of personnel, organizational effectiveness, and so forth of both organizational forms, i.e., a transportation company vis-á-vis single modal carriers, have been implicitly assumed to be of equal effectiveness. The validity of this assumption will be discussed at length in Chapter VI.

Geographical factors such as weather or climate conditions and the geographical terrain over which a carrier operates are concerned, as the name implies, with the geographical environment of a carrier's route structure. Since the railroad and trucking company and the transportation company will operate over the same route system these factors will not be directly considered in the comparison between these organizational alternatives. That is, the operations of the two single modal firms will be compared with the operations of a transportation company which has the same route structure and hence would face the same climatic and geographical conditions. These environmental factors will be considered indirectly, however, as such factors would affect the cost of movement over the route system of the carriers.

Commodity factors are characteristics of the goods, which create differences in the costs of movement. For instance, one class goods may have loading characteristics which would require special handling techniques which would require additional labor or capital outlays by the carrier thus affecting the cost of movement. As mentioned in Chapter II, commodity factors will not be addressed in the study. This is because the rail and truck modes have literally thousands of commodities many which have characteristics which affect the cost of movement. If one were to consider a number of commodities, the number of decision variables developed in the previous chapter would have to be multiplied by the number of commodities considered. Thus for the sake of simplicity the study will concentrate on the "average commodity subject to intermodal competition for movement." While this simplification may effect the generality of the results of the study to some extent, the object of the study is to obtain a broad picture of the effects of the factors considered rather than to concentrate on specific movements of certain commodities.

Furthermore this simplification may not be as serious as it first appear . For instance it is not likely that the commodity characteristics of a shipment of canned corn differs substantially from a shipment of canned motor oil. Nor is it likely that the characteristics of stoves differ substantially from those of washing machines. In other words, there are classes of goods for which the commodity characteristics are substantially the same. In fact, the classification of goods into a relatively small number of groups is the starting point for the carriers rate determination process.

> That is, each of the hundreds of thousands of shippable commodities, ranging from aardvarks to zymometers, is placed (classed or classified) in some one of a relatively small number of "classes". Then instead of shipping a commodity, in effect one ships a certain quantity of a certain "class".[1]

This fact would enable the solution of the model for "the average commodity subject to intermodal competition" to remain valid for a number of commodities. A solution for each specific class of goods could be obtained by using the average costs applicable to that class. While this endeavor should be of interest to the firms which may be interested in forming a transportation company, this is not necessary to obtain a broad picture of the effects specific factors have on the operating characteristics of a transportation company, which is the object of this dissertation.

Route factors may be conveniently classified into two groups for purposes of discussion. Internal route factors are those factors

[1] Sampson and Farris, op.cit., p. 162.

which the carriers can contol to some extent. Examples of internal route factors are carrier operating ratios, load factors, and carrier capacity. External route factors are those factors over which the carriers can exert little or no influence. One external route factor would be the level of shippers' logistics constraints. Thus, examination of the route factors lies at the heart of the purpose of this project. That is the effect each of these factors has on the operations of a transportation company compared with the operations of the single modal carriers should indicate whether it is possible for a transportation company to achieve economies from the reallocation of traffic from high to low cost modes. These route factors are the test factors which will be analyzed in the study to determine the effect they have on the economic performance of the transportation company and the single modal carriers.

Internal Route Factors

The internal route factors which will be studied in this thesis are: (1) the operating ratios of the composite single modal companies; (2) alternate levels of load factors of these companies; (3) the capacity of the carriers; and (4) the size of shipments.

The levels of the factors may be considered to be an upper bound and a lower bound of the factors. In other words, the value of a particular factor for most companies should lie between these bounds. Thus the evaluation of the changes in the level of these factors should provide insights as to how these factors would affect the economic consequences of a transportation company formed by carriers with factors which lie between these bounds.

Carrier Operating Ratios

As stated in Chapter I, one of the potential sources of economies resulting from the formation of a transportation company is the possible reallocation of traffic from the high cost mode to the low cost mode on a particular route segment. Examination of carrier operating ratios, both truck and rail, should give insights as to whether or not this is possible. The operating ratio is the ratio of operating expenses to operating revenues. Thus the operating ratio of a carrier directly affects the contribution to fixed and/or common costs including profit margin which may influence the manner in which the carriers make equipment allocation decisions. One would be interested in determining if a change in the level of the rail and truck operating ratios causes the equipment allocations of the transportation company to be significantly different from the manner in which the single modal carriers allocate their equipment. Another question of interest is whether a change in the operating ratios causes the contribution of the organizational alternatives to be significantly different. As will be explained in the next chapter, various performance measures will be calculated from the simulation runs which will be helpful in answering these questions.

The specific operating ratios which will be considered are 99% and 91% for the trucking firm representing a below average or inefficient carrier and a well managed carrier, respectively. The operating ratios for the rail mode will be 85% and 65% representing an inefficiently and an efficiently managed carrier. Within these spectrums one would find the average carrier.[2]

Carrier Load Factor

The load factor of a carrier shall be defined to be the average payload transported over the carrier's route system. In other words, the load factor is the average weight of shipments transported between origins and destinations. The load factor of a carrier directly affects the cost of movement, as will be explained in detail in a later section of this chapter. Thus, this factor should have a direct bearing on the manner in which carriers allocate their equipment and on the profitability of the firm. Also of interest would be the manner in which operating ratios and load factors interact to affect carrier allocations and resulting profits and cost to users.

The specific load factors which will be analyzed for the trucker are 100 Cwt. and 300 Cwt. representing a low load factor and a high load factor, respectively. The load factors for the railroad will be 400 Cwt. and 800 Cwt. representing a low load factor and a high load factor.[3]

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[2] The average operating ratio for Class I and II motor carriers was 96.2% in 1970. ("American Trucking Trends 1970-71", op.cit., p. 19). The approximate average operating ratio of Class I railroads was 79% in 1969. ("Yearbook of Railroad Facts", 1970 Edition, Economics & Finance Department, Association of American Railroads (Chicago, Illinois: April 1970), p. 9.)

[3] The average load factor for Class I motor carriers of general freight was 264 Cwt. in 1969. ("American Trucking Trends 1970-71", op.cit., p. 34.) The average weight of a carload of rail freight was approximately 528 Cwt. in 1969. ("Yearbook of Railroad Facts", op.cit., p. 50.)

Size of Shipments

The study will segregate movements into two categories truckload (TL)/carload (CL) movements and less-than-truckload (LTL) movements. This distinction is necessary because the cost characteristics in the TL/CL movements are different from those of LTL movements. The reasons for these differences as well as the nature of these differences will be explained in a later section of this chapter.

TL and CL quantities shall be defined to be shipments which are capable of being moved in either a truck trailer or a boxcar. In other words, the TL/CL shipments received from the shippers are large enough to be transported by a number of truck trailers or a (different) number of boxcars. Thus, TL/CL shipments can be moved by truck, piggyback, or by rail, subject to shippers' logistics constraints.

LTL shipments are those which are not large enough to fill a truck trailer. Since the railroads have phased out there less-than-carload (LCL) business, these types of shipments are subject to movement by truck or piggyback only.

Capacity of the Carriers

The capacity of the carriers should also affect the manner in which the carriers make their capacity allocations and thus affect the profitability of firms. This factor may also affect the price users pay for transportation services. Like the other factors discussed, the capacity of the system will also assume two levels. That is, the system wide capacity of the carriers will be studied for effects at two levels. The lower level of the system will be defined to be that combination of carrier capacities which is capable of meeting all the expected demand requirements for movement within the system. Whether or not the carriers allocate their equipment in such a manner as to meet that demand is subject to analysis. The upper level of system capacity shall be defined to be that amount of capacity owned by each mode such that no one would add additional capacity. In an operational sense, the upper level of system capacity will be that amount of capacity such that each carrier is capable of meeting at least all the expected demand requirements within the system.

The capacities of the carriers have been segregated into two groups--a certain amount of capacity has been reserved for TL/CL movements and a certain amount has been reserved for LTL movements. In the real world it is very unlikely that a carrier would segregate its equipment into such groups. This artificiality was introduced so that the two classes of movements--TL/CL versus LTL--could be studied separately to determine if the different organizational approaches (transportation company versus single modal carriers) have significantly different economic consequences in so far as the two market segments are concerned. Although the simulation could have dealt with the total market segment by using average costs of movement including both CL/TL and LTL in the same cost figure, this would have lost the information as to how the organizational forms perform under the size of shipment parameter.

The amount of capacity set aside for each type of movement by the modes is also somewhat arbitrary. For instance, the specific percentage of capacity reserved for TL movements by the trucker may be relatively large as compared to what one may find in the real world. That is the trucking mode in the simulation has reserved an amount of capacity equal to that which the railroad has reserved for CL movements. This may indeed not be the usual case in the real world. It must be stressed, however, that although this capacity split is arbitrary, for comparison purposes it is consistent. The performance of a transportation company will be compared with the performance of single modal carriers operating with exactly the same set of parametric and random values. As will be discussed in great detail in Chapter V, the analysis will focus attention on whether or not there are significant differences in the performance between the two organizational approaches. Hence it is of greater importance in this study that the parametric and random components be internally consistent between the approaches than is the absolute values of the parameters. More will be said about this matter of internal consistency in the next chapter.

Before proceeding further, it should be pointed out that in practice the rail mode would also not allocate a certain amount of capacity for piggyback LTL movements as this study has done. Again this was done to determine if the two transportation approaches would result in a different equipment allocation pattern and consequently result in significantly different economic consequences.

External Route Factors

The external route factor which will be studied in this thesis is the level of the shippers' logistics constraints. The size of the shippers' logistics constraints will also assume two alternate levels.

Shippers' Logistics Constraints

Since shippers' logistics constraints directly affect the manner in which carriers allocate their equipment, this factor will definitely affect the economic situation of carriers. It has been assumed that the logistics constraints of the shippers must be satisfied. This is not an unreasonable assumption given that certain shippers' logistics systems dictate the movement of goods must be allocated to specific modes. The carriers should also be expected to satisfy a guaranteed market before they would enter the competitive traffic market.

As was mentioned earlier, the size of these logistics constraints determine the size of the market which is subject to movement by more than one mode. The second level corresponds to the situation where the logistics systems of shippers does not constrain the allocation of equipment by the carriers to a large extent. In other words, the second level of this factor provides for most of the market being subject to intermodal competition. The first level of this factor constrains the solution along modal lines to a much greater extent. Examination of this factor should provide guidelines as to under what competitive circumstance, if any, a transportation company would out perform single modal companies.

Other Specifics of the Model

This section will identify the random components of the model and will present the shipper's modal selection policy. There are two random variables incorporated into the simulation model. These are: (1) The forecast of the market share of competitive inter-modal traffic the carriers predict they can obtain; and (2) The demand for transportation services between specific points.

Carrier Market Share Predictions

The market share of the traffic subject to intermodal competition, each carrier predicts he can obtain, will be treated as a random variable in the study. This is in keeping with the difficult real world problem of forecasting market shares. The market share a firm obtains is determined by a number of factors and complex interactions. For example, the market share a transportation firm obtains is dependent upon, among other things, the general economic conditions, the service reputation of the firm, the effectiveness of the firm's advertising/sales program, and the logistics systems of shippers. Thus the market share a firm predicts it can obtain is likely not to be 100% accurate. The firm may over estimate its market share or under estimate its market share as well as possibly having an accurate prediction. It is because of the large number of interactions and uncertainties involved in the estimation of market shares that the prediction of market shares a carrier will obtain will be treated as a random variable.

The values the variable may assume for the trucker and railroad will be 40%, 50%, and 60% of the market subject to intermodal competition. In other words, when these carriers can compete for traffic, they will estimate they can obtain either 40%, 50%, or 60% of that market for a particular route segment. The particular estimate for each route segment will be determined by a table of random numbers. When a carrier cannot compete on a given segment, the other carrier will attempt to estimate the size of this market and if profitable allocate equipment to it. The values in this case will be 80%, 90%, 100%, 110%, 120% of the market. Thus for any given route segment, the carriers may over estimate the market which would result in excess capacity at some nodes or they may under estimate the market resulting in unsatisfied demand between some points or they may exactly estimate the market which would satisfy all demand and leave a minimum of excess capacity.

The transportation company, likewise, is confronted with the same market prediction problem. The values of the estimated market share the transportation company expects to obtain will be 80%, 90%, 100%, 110%, and 120% of the market subject to intermodal competition. The particular estimate for each route segment on a particular run will be determined by summing the single modal carrier's estimates in order to preserve internal consistency. In other words, if on a particular run the trucker estimates he can obtain 60% of the intermodal competitive market on one segment and the railroad estimates it can obtain 50%, the transportation company would estimate the size of the market at 110% of its true size. In essence, this allows one to make a cross comparison between the performance of the single modal companies vis-á-vis the transportation company in which not only are the parametric values the same but also in which the random components are consistent across the organizations.

The Demand for Transportation Services

The demand for transportation services between any two points is determined to a large extent by the demand for shippers' products. If the product is manufactured at point A and there is demand for the product at point B, the product must be transported between these points. A more succinct way of stating this proposition is that transportation provides time and place utility in goods. Viewed from the carriers perspective, the demand for transportation services can be thought of as a random variable. The variability of the size of the transport market is of course directly related to the problem the carriers have in predicting their market share.

The size of the transportation market subject to intermodal competition will be allowed to assume three values, a high volume of traffic, an average volume of traffic, and a low volume of traffic for each size of shipment level. The specific level of demand between specific points will be determined by a table of random numbers.

Shippers' Modal Selection Policy

In the competitive single modal company situation, the carriers must determine if they can compete in a market segment subject to intermodal competition. If they can, they must allocate equipment to that segment consistent with their forecast of the amount of traffic they can obtain in that segment. If the carriers allocate more equipment to a segment than there is demand and if this allocation results in more than one method of movement being offered to shippers, the shippers must chose the manner in which to move their goods. These methods have no service differences (or these differences are unimportant as perceived by the shippers), or else the shippers specific needs would have been included in the logistics systems constraint.

If the carriers have collectively under estimated the amount of traffic subject to intermodal competition, the shippers have no choice but to accept what is offered, up to 100% of the demand being met. If the carriers over estimate this market, the shippers must choose what methods of movement they will use. Under these circumstances, the following shippers' modal selection policy will be adopted: The shippers will allocate their traffic equally between the carriers. This is in keeping with the assumption that when the service of competing carriers is equal the shippers have no real preferences between the modes.

In the case of the transportation company, operating under the assumption that it will face the same demand pattern as the single modal companies of which it is comprised, there may be no need for a shippers' modal selection policy. This is so because the transportation company would most probably allocate only one method of movement to any competitive market segment.

Recapitulation of the Test Factors

Due to the length of the preceding discussion, a recapitulation of the test factors, shippers' modal selection policy, and the random components of the model is in order. The test factors and their appropriate levels are outlined in Table I. Table II displays the random components of the model and describes the shippers' modal selection policy.

Generation of the Data

As stated in Chapter I, the data which will be used in this study will be hypothetical. This section will explain in detail how the data will be generated for use in the simulation model. The discussion will also focus on an explanation of which test factors affect the cost of movement and the manner in which they effect these costs.

The costing figures used in this study will be on a per hundred weight (Cwt.) basis. These costs will be ascertained by allocating the total costs between specific origins and destinations on the basis of the amount of Cwt.'s transported between them. Once the full costs of each mode have been determined, the pricing mechanism explained in the last chapter will be utilized to determine the appropriate rates between two points. A computer program has been developed to calculate the full costs of the modes. The costs will differ each time a parameter is varied.

TABLE I

MODEL VARIATIONS

Test Factors	Symbol		Level 1 (Standard)	Level 2 (Alternate)
[illegible] ratios	A		99%	91%
	B		85%	65%
[illegible]	C		100 Cwt.	300 Cwt.
	D		400 Cwt.	800 Cwt.
[illegible]	CS		TL, CL	LTL
[illegible] TL, CL movements [illegible] of expected demand	E		High Level	Low Level
		Truck	100%	50%
		Rail Truck	60%	30%
		Flatcar	80%	40%
		Boxcar	100%	50%
[illegible] for LTL movements as [illegible] of expected demand		Truck	200%	100%
		Rail Truck	60%	30%
		Flatcar	80%	40%
[illegible] constraints [illegible] traffic percentage of [illegible] to each mode	F		High Level	Low Level
		Total Traffic Constrained	80%	20%
		%Truck	40%	40%
		%Rail Boxcar	60%	60%
[illegible] traffic percentage of [illegible] to each mode		Total Traffic Constrained	80%	20%
		%Truck	100%	100%

TABLE II

OTHER MODEL SPECIFICS

RANDOM COMPONENTS:	VALUES OF RANDOM VARIABLES
A. Carrier Market Share Estimates	
1. Trucker	40%, 50%, 60%
2. Railroad	40%, 50%, 60%
3. Transportation Company	80%, 90%, 100%, 110%, 120%
B. Demand for Transportation Services on Each Route Segment	
1. CL, TL Shipments	30,000 Cwt; 60,000 Cwt; 90,000 Cwt.
2. LTL Shipments	15,000 Cwt; 30,000 Cwt; 45,000 Cwt.

SHIPPERS' MODAL SELECTION POLICY:

If the carriers have collectively under estimated the amount of traffic subject to intermodal competition, the shippers have no choice but to accept what is offered, up to 100% of the demand being met. If the carriers collectively over estimate this market, the shippers will allocate their traffic equally between the carriers.

The Costing Categories

There are many costing categories one could use for analyzing the cost of moving goods. The following cost categories have been chosen because they reveal information about the effects of changing parameters in the system have on costs. As mentioned previously, full costs will be composed of a profit margin, fixed and/or common costs, and out-of-pocket costs. Out-of-pocket costs will [illegible] into the [illegible] or over-the-road costs, pick up and delivery or car spotting costs, terminal costs, and billing costs.

> Line-haul costs are defined as the movement over the road [or road bed], either from one terminal to another or, in some cases, from a shipper's location to destination. Terminal costs are defined as the handling and reworking of freight to match origins and destinations of outgoing and incoming freight. Pickup and delivery costs are defined as the function of picking up and delivering freight within a specified terminal area. Billing ... costs are those related to paper work costs for each shipment.
>
> Each of the out-of-pocket costing categories is measured in terms of its relevant service unit. A service unit is the appropriate variable assigned to a specific costing category. This concept is exactly the same as that used in general accounting in cost allocation. The accountant also must find some method of allocating indirect costs such as rent. ...
>
> The service units for line-haul costs are vehicle hours and vehicle miles, because some costs in the line-haul category vary with time (e.g., drivers' wages) and others vary with distance (e.g., fuel).[4]

Line-haul costs also vary with the amount of product carried. Thus, an appropriate measure for line-haul costs would be the sum of the total mileage costs (distance) and total hourly costs (wages) divided by the total number of Cwt.-miles transported by the carrier in a given period.

The costs calculated in this manner represent the cost of moving the average product with the average system load factor over the average length of haul. To convert the line-haul cost/Cwt.-mile to the average system line-haul cost/Cwt., etc

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[4] [illegible]

would simply multiply the line-haul cost/Cwt.-mile by the average length of haul. For example, if the average line-haul cost/Cwt.-mile was .35 cents/Cwt. mile and the average length of haul was 300 miles; the average line-haul cost/Cwt. would be 105 cents. To convert the average line-haul cost/Cwt. to specific line-haul costs between two points with a specific load factor, one would multiply the average figure by the ratio of the actual length of haul/system average length of haul and divide by the ratio of the actual load factor/average load factor. For instance, if the average line-haul cost was 105 cents/Cwt. based on an average load factor of 300 Cwt. and average length of haul of 300 miles, the specific line-haul cost for a movement of 150 Cwt. over 900 miles would be:

$$\text{average line-haul cost} \times \frac{\text{actual distance}}{\text{average distance}} \div \frac{\text{actual load factor}}{\text{average load factor}} = \text{actual line-haul cost}$$

$$(105 \times 900/300) \div (150/300) = 630 \text{ cents/Cwt.}$$

> As with line-haul costs, pickup and delivery costs have service units associated with time (drivers' wages) and distance (fuel). ...Dividing the total pickup and delivery costs by the total Cwt. [handled in the system] gives a cost per Cwt.[5]

For the rail mode under consideration, these costs will be defined as "car spotting" costs including the movement of the car to and from the classification yard. The pickup and delivery cost (PUD)/Cwt. varies inversely with the size of the shipment; the specific

[5] Ibid., p. [illegible].

PUD cost/Cwt. for a movement with a specific load factor can be obtained from the system average figures by dividing by the ratio of the specific load factor/system average load factor.

Terminal costs will be measured in the same manner as PUD costs, i.e., on a per Cwt. basis. The discussion in the previous paragraph of how to convert to specific average costs/Cwt. for given load factors are applicable to this category of costs also.

Billing costs are the expenses associated with the paperwork functions per movement. The average billing cost/Cwt. is obtained by dividing this somewhat constant cost by the system average load factor in Cwt. To convert this average cost to a cost/Cwt. for particular movements, one would divide by the ratio of the particular load factor/system average load factor.

The above out-of-pocket costing categories are derived from the recognized I.C.C. standard accounting system for motor carriers. Rail carriers have different costing categories such as switching and yard expenses but in order to have a basis for comparison the above categories will be used for both modes.

As alluded to above, the line-haul out-of-pocket costs for the rail mode will consist of the line-haul transportation, maintenance of way and structures, and maintenance of equipment expenses associated with line-haul movements. PUD and terminal out-of-pocket costs for the rail will consist of transportation, maintenance of way and structures, and maintenance of equipment [illegible] associated with yard operations such as car spotting, switching, and classification of freight. Billing costs are comparable as they stand.

Once the out-of-pocket costs have been calculated, one must allocate a portion of the total systems fixed, and/or common costs to a particular movement to determine the fully distributed costs for that movement. Fully distributed costs are found by adding a percentage of each out-of-pocket cost category to cover common costs that do not vary with traffic. These would consist of officer's salaries, depreciation, and the like. The Cost Finding Section of the Bureau of Accounts of the Interstate Commerce Commission have found common costs to be about 10% and 20% of fully distributed costs for motor carriers and railroads, respectively.[6] Thus, to find the fully distributed cost for a movement for the motor carrier and railroad, one would take the average out-of-pocket costs and divide them by 90% and 80% respectively.

The final adjustment for costing is a profit allowance. In this study the profit allowance will be made through the operating ratio. From standard accounting practice, the operating ratio is defined as the operating expenses divided by operating revenue.[7]

[6] See "Explanation of the Development of Motor Carrier Costs with Statement as to their Meaning and Significance," I.C.C. Statement No. 4-59, Washington, D.C., [illegible] I.C.C. Statement No. 7-63, Washington, D.C., 1963.

[7] [illegible]

Average Industry Cost Data

As mentioned in the introduction to this section, the research will utilize approximate industry data in the various costing categories so that the study may deal with carriers which reflect the differences in operating characteristics between modes. Table III presents the average cost structures for the rail and truck modes.[8] The cost structure of the trucking mode is an average which includes both TL and LTL movements. The cost structure of the rail mode is based on CL movements.

TABLE III

PERCENTAGE BREAKDOWN OF RAIL AND TRUCK COST STRUCTURES

	Truck	Rail
% variable	90%	80%
Out-of-pocket costs		
Line-haul costs	64%	67%
PUD (car spotting) cost	18%	10%
Terminal (switching & classification) cost	14%	20%
Billing cost	4%	3%

[8]The percentage breakdown of out-of-pocket costs by costing category for the motor mode in the table above was obtained largely [illegible] John R. Meyer, et al., The Economics of Competition in the [illegible]portation [illegible] [illegible]

The study will segregate movements into two categories TL/CL movements and LTL movements. This distinction is necessary because the cost characteristics of the TL/CL movements are different from LTL movements.

Truck Cost Data

For TL movements, the cost structure for truckers given in the preceding table is not appropriate. This is due to the fact that a substantial portion of trucking business is LTL and necessitates larger expenditures on PUD and terminal costs than do TL movements. The average cost structure for truckload movements will be derived in the following paragraphs.

The average revenue for truckers hauling general commodities is approximately 7 cents/ton-mile; and the average length of haul is about 300 miles.[9] Multiplying the revenue figure by the average length haul yields the average revenue per ton of \$21.00 or \$1.05/Cwt. The average load factor of the trucker will be taken to be 200 Cwt./vehicle movement.

As explained above one of the parameters that will be varied is the operating ratio of the carriers to determine what effect this has on the profitability of the transportation company and on the use of coordinated transportation. The analysis will focus attention on two different operating ratios for each mode. These

[9] In 1966 the average revenue for Class I intercity [illegible] carriers was approximately [illegible] haul [illegible] p. 21 [illegible]

ratios will be 99% and 91% for the trucking mode representing a below average or inefficient carrier and a well managed carrier, respectively. Within this spectrum one would find the average carrier.

Multiplying the average revenue per Cwt., just calculated, by the operating ratios and then utilizing the breakdown of the average cost structure of motor carriers in Table III yields the average trucking costs per Cwt. displayed in Table IV.

TABLE IV

TRUCKING AVERAGE COSTS PER Cwt.

Load factor	200 Cwt.	200 Cwt.
Operating ratio	91%	99%
Total revenue	1.050	1.050
Profit margin	.0945	.0105
Common costs	.0955	.1040
Total Out-of-pocket costs	.8600	.9355
Line haul costs	.5504	.5987
PUD cost	.1548	.1684
Terminal cost	.1204	.1310
Billing cost	.0344	.0374

The TL PUD costs should be approximately half of the average PUD costs because only one stop must be made to load the trailer. The TL terminal costs needed to handle shipments across the plat form [illegible] when small shipments could be added to the TL at the terminal, since the trailer could be moved direct from the customer's door to destination. Billing costs should drop also, perhaps as much as one-half, since there will usually be only one billing per vehicle with TL movements. Deleting these costs from out-of-pocket costs and recomputing common cost and profit margin by dividing the out-of-pocket costs by the % variable then dividing this figure by the operating ratio yields the TL average costs per Cwt. displayed in Table V.

TABLE V

TL AVERAGE COSTS PER Cwt.

Operating ratio	91%	99%
Load factor	200 Cwt.	200 Cwt.
Total revenue	.790	.790
Profit margin	.071	.008
Common costs	.072	.078
Total out-of-pocket costs	.647	.704
Line-haul cost	.551	.599
PUD cost	.077	.084
Terminal cost	----	----
Billing cost	.019	.021

Thus the average revenue for TL movements which will be used in the study is 79 cents/Cwt.

The percentage breakdown by costing category for TL movements is given in Table VI.

TABLE VI

PERCENTAGE BREAKDOWN OF TL COSTS

% variable	10
Out-of-pocket costs	--
Line-haul cost	86%
PUD cost	12%
Terminal cost	--
Billing cost	2%

Using the overall average trucking costs per Cwt. and the derived TL average costs per Cwt., one can determine the LTL average costs per Cwt. in each costing category. This is so because the overall average trucking costs per Cwt. are a weighted average of the LTL and the TL costs. Mathematically, W_1(LTL Cost) + W_2(TL Cost) = Average Cwt., where the weights, W_1 and W_2 are the percentage of Cwt. which are LTL and TL, respectively.

The percentage of LTL traffic carried by regulated general commodity carriers is approximately 50%,[10] so the percentage of TL

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[10] Last year Class I and II motor carriers of general freight carried approximately 83,223 million tons of LTL freight. The 1969 total tonnage of freight carried by Class I and II motor carriers of general freight was 172,100 million tons. Dividing the LTL tons by the total tons yields W_1 = .48. The figures used in deriving this figure were obtained from "Transportation Facts and Trends", Eighth Edition, Transportation Association of America, Washington, D.C., 19[illegible] and "[illegible] 1970-71", op. cit., p. 1[illegible].

traffic is approximately 50%. Using these weights and the data in the other two tables the LTL cost data was calculated and is presented in Table VII.

TABLE VII

LTL AVERAGE COSTS PER Cwt.

Load factor	200 Cwt.	200 Cwt.
Operating ratio	91%	99%
Total Revenue	1.310	1.310
Profit margin	.118	.013
Common costs	.119	.130
Total out-of-pocket costs	1.073	1.167
Line-haul costs	.551	.599
PUD costs	.232	.252
Terminal costs	.240	.262
Billing costs	.050	.054

Rail Cost Data

The average revenue for railroads in 1969 was approximately 1.35 cents/ton-mile; and the average length of haul was about 600 miles.[11] The average revenue figure will be adjusted upward to 4 cents/ton-mile because the former figure includes a large number of bulk movements of low intrinsic value which would not be subject to competition from the truckers. Hence, general

[11] In 19[illegible] ... per ton-mile was 1.3[illegible] cents; the average length [illegible] ... ("[illegible] Facts", op. cit., [illegible])

commodities subject to competition for movements by rail and truck would have higher costs of handling and demand greater rates. Multiplying the average length of haul and the average revenue figure yields the average revenue figure of 120 cents/Cwt. Using an average load factor of 600 Cwt. and the average cost structure of railroads presented above, the cost data in the following table were calculated. The operating ratios for the rail mode will be 85% and 65% representing an inefficiently and efficiently managed carrier.

TABLE VIII

RAIL AVERAGE COSTS PER Cwt.

Load factor	600 Cwt.	600 Cwt.
Operating ratio	65%	85%
Total revenue	1.20	1.20
Profit margin	.42	.18
Common costs	.156	.204
Total out-of-pocket costs	.624	.816
Line-haul costs	.418	.547
PUD costs	.062	.082
Terminal costs	.125	.163
Billing costs	.019	.024

Piggyback Cost Data

Once the average cost categories have been developed for the single modal carriers, these costs can be used in computing the cost of piggyback transportation. A piggyback movement entails using a highway tractor and trailer for pickup and delivery operations and transferring the trailer to a railroad flatcar for line-haul transportation between two points. Hence, piggyback movements are coordinated rail-truck operations and as such, the cost of these movements embody selected cost characteristics from each mode.

> [A] ...simplification of the transportation process in piggyback is the by-passing of railway yard classification at the origin and destination. Piggyback operations need as an initial classification yard nothing more than a trailer ramp site with a parking lot. Classification of cars by destination usually can be accomplished in the process of loading the trailer onto flatcars at the origin. Also classification yards enroute can be by-passed to a large extent. Switching enroute under most circumstances might be done by diesel road-switcher locomotives simply dropping cars at trailer ramps located outside major cities.
>
> . . . .
>
> Like trucking costs, piggyback costs usefully are divided into terminal and line-haul expenses. Terminal expenses, in turn, can be separated into those conventionally associated with truck transportation and the peculiarly piggyback costs of loading and unloading the highway trailer onto and off the railway flatcar and the cost of making up the piggyback train.
>
> Piggyback pickup and delivery costs are essentially the same as those...concerning over-the-road truck operations.[12]

More specifically, the line-haul costs for piggyback movements will be those of the railroad adjusted for differences in

[12] Meyer, et al., op. cit., pp. [illegible] and [illegible].

load factors. The piggyback PUD costs will be those associated with two highway trailers plus a cost of $4 or $2 for moving each flatcar into loading and unloading position and building and breaking the train, for the railroads with operating ratios of 85% and 65%, respectively. The piggyback terminal costs will be those of the highway mode plus a $9 or $5 charge per trailer for loading and unloading the trailers on and off a flatcar for the inefficient and efficient railroad respectively.[13] The piggyback billing costs will be the sum of the costs for two trailers and the average rail billing cost.

The piggyback common costs will be obtained by dividing the rail and truck cost contributions for this type of movement by the corresponding percent variable--80% and 90%, respectively. The piggyback profit contribution will be determined by dividing the full costs contributed by each mode by the appropriate operating ratios. For instance, if the out-of-pocket trucking costs were $27 and the out-of-pocket rail costs were $32, the out-of-pocket plus common costs for this movement would be $27/.9 + $32/.8 = $30 + $40 = $70. The full cost of this move would be

[13] Mr. G. W. Telfer, Manager of TOFC, Burlington Northern Railroad indicated that the approximate cost of loading and unloading trailers onto flatcars was $5.00/trailer. Mr. Telfer also stated that the switching costs for moving flatcars into loading and unloading positions was approximately $45.00/hour and that a switcher on the average could handle 25 cars/hour. Thus the switching and loading costs used in the study are in the range that is representative of the real world.

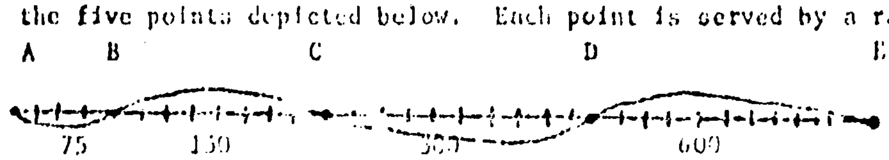
(30/.91 + 40/.65) = \$33 + \$61 = \$94, for a trucker with an operating ratio of 91% and a railroad with an operating ratio of 65%.

The cost data which will be used in this study are average costs. There are certain dangers involved when one uses average costs. Average costs are dependent on the volume of "production". If one is dealing with a well-established on-going frim in which the average "production" costs have remained relatively stable over the past several years, then one can feel relatively at ease in utilizing past average cost data for determining future courses of action, at least within some range. For most large transportation firms, the average cost per Cwt. moved are relatively stable since outputs are large and expected increments in output small by comparison.

The Transportation System

The previous section has identified the costing categories and presented the average costs in each category that will be used as the foundation for analysis. The section also indicated how the various parameters would impact on each of the costing categories. This section will identify the transportation system that will be investigated.

The transportation system which will be studied consists of the five points depicted below. Each point is served by a railroad



and a motor carrier and a transportation company composed of the two carriers. Point B is located 75 miles from A, C is 150 miles from B, D is 300 miles from C, and E is 600 miles from D.

The average costs presented in the previous section will provide the basis for determining what the average costs are between each origin and destination above. In other words, one would multiply the average line-haul costs by the ratio of the actual distance/system average length of haul for the modes, then readjust common costs and the profit allowance. For instance, if the average line-haul cost was 105 cents/Cwt. based on an average load factor of 300 Cwt. and average length of haul of 300 miles, the specific line-haul cost for a movement of 300 Cwt. for 900 miles would be $(105 \times \frac{900}{300}) = 315$ cents/Cwt. This line-haul cost would be added to the other out-of-pocket costs, PUD, terminal, and billing. The out-of-pocket costs would be divided by the % variable for the particular mode to obtain the common plus out-of-pocket costs. This figure would be divided by the operating ratio of the mode to determine the full costs of the movement.

Considering movements both to and from specific points in the above transportation system, there are 20 different route segments. These are movements, from left to right, A to B (designated AB), AC, AD, AE, BC, BD, BE, CD, CE, and DE. The corresponding moves in the other direction are ED, EC, EB, EA, DC, DB, DA, CB, CA, and BA. Movements in both directions should be considered because in general most transportation systems do not have balanced traffic patterns or even the same geographical conditions in both directions which cause the costs of movement to differ with the direction of movement. This thesis will, however, limit the route segments considered to those unidirectional movements from left to right.

This simplification described in the previous paragraph will reduce the computational requirements by one half and will not affect the integrity of the results. The reason why attention need be focused only upon unidirectional movements in this thesis is that each factor which would make the directional movements have differing costs will be examined for effects at both levels (in different runs) during the simulation. So in actuality, both directional movements are being considered in different runs, even though the lettering of the movements is unidirectional.

CHAPTER IV

EXPERIMENTAL DESIGN

This chapter will focus attention on the nature of the experimental design as well as the analytical and statistical methodology used in the dissertation. Four specific areas of the experimental design aspects of the dissertation will be discussed. First the problem of realism in simulation will be addressed. Second, attention will focus on the nature of the output of the simulation. Next, the performance measures used to describe the output of the simulation will be presented. Finally, the specific experimental design which was utilized will be discussed.

The Problem of Realism in Simulation

One of the most important problems one faces when utilizing simulation to investigate a new or proposed system is that of insuring that the model is an accurate representation of the system being analyzed. Chervany has succinctly summarized the problems of using simulation models to analyze real world problems as follows:

> In the development and analysis of simulation models, the most persistent problem concerns the realism of the model being manipulated. A simulation model presents a perfect opportunity for "controlled" experiments. The various factors under analysis can be varied one (or more than one) at a time while all other constructs are held constant. This analytical capability, however, is not achieved free of cost. The price that is paid is the persistent problem of insuring that the simulation model being used is an accurate representation of that part of reality that is being analyzed. While this problem of

realism arises in all model-building attempts, it seems to be even more troublesome than usual in simulation studies.

Although this realism problem assumes many forms, it seems that there are two basic hierarchial levels that generally appear. The first level concerns the structural form--model subsystems and subsystem interrelationships--of the model being simulated. The second level focuses upon the determination of the specific data inputs that are required to make the model analytically operational.[1]

Structural Realism

The problem of structural realism focuses on the selection of elements to be included in the model and the manner in which they are connected. The following questions are typical of those that must be answered at this level: Do the variables included in the model accurately reflect the important constructs found in reality? Are the variables omitted from the model sufficiently unimportant that failure to consider them will not bias the conclusion drawn from analysis of the model?

. . . .

Since the firm [s] being modeled in this project...[are] hypothetical, the ability to test the model for structural realism is somewhat limited. ...

. . . .

...., C. P. Bonini has suggested an approach to validation in simulation of hypothetical organizations. Concerning his model of decision and information systems within a hypothetical firm, he states:

> The first question to be asked about our model would properly be, "Does the model correspond to the real world?" In other words, "Do the information and decision systems reasonably represent real-world situations?"
>
> We would not expect, of course, the model to be an exact replication of the real world--all models are simplifications to some degree. ... We do believe, however, that the model is a reasonable representation of real-world

[1]Chervany, op.cit., pp. 143-144.

> behavior. We cannot, of course, completely validate this belief, but what we can and will do is to set forth the major ingredients of our decision rules for separate examination. We will attempt to justify these rules by relating them to existing theory in the scientific literature of economics, accounting, or the behavioral sciences, or to the literature on business practice.[2]

The structural form of this model was developed along the lines suggested by Bonini. It should be stressed at this point, however, that the model is a simplification of the real world. The hypothetical firms modeled in Chapter II are assumed to react in all situations to maximize their profit contributions. The model has not considered any social welfare role that many modern business concerns have adopted. To the extent that transportation firms do not attempt to maximize profit, whether due to the fact that they are limited goal satisfiers or due to the fact that they have some social welfare role to fulfill, the results of this project are limited to that degree.

Furthermore, as mentioned in the previous chapter, the management and operations personnel as well as the organizational structure of these firms are considered to be capable of reaching their goal of profit maximization subject to the uncertainties of predicting the market shares obtainable. The dissertation has also not addressed the real problems of how scheduling operations must be

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[2]*Ibid.*, pp. 144-47, quoting from Charles P. Bonini, *Simulation of Infor[illegible] in the Firm* ("The Ford Foundation Doctoral Dissertation [illegible]", Englewood Cliffs, New Jersey: Prentice-Hall, Inc., [illegible]), p. [illegible].

accomplished to have the equipment needed at the right place at the right time in order to maximize profits. While these are definite limitations of the analysis, all firms considered have the benefit of these simplifications. Thus the end result is that they will hopefully cancel each other out in the study.

What happens when the results are attempted to be applied in the real world? To the extent that imperfect scheduling operations, and different levels or quality of personnel are found in the real world, the object of profit maximization will suffer. The author would argue, however, that even with these qualifications the results of the study should still be a valid indicator of which combinations of factors or firms processing specific levels of factors should lead to significant economies as a result of forming transportation companies from two single modal carriers. At least the factors which are found to be significant in the analysis of the results of this simulation should provide a basis for predicting which combinations of factors should lead to significant economies.

There is one other area in which the model differs from the real world. The model which has been developed considers a transportation system over which operates only one railroad company and one trucking company and compares the operating results of this system with the operating results which are obtained when a transportation company operates over the same system. It is not likely in the real world that a transportation system, or a substantial portion of a system, would be served only by one railroad and one trucking company. It is far more likely that on a given system, or segment of a system, that there will be more than one firm in each mode competing for the available traffic. Thus, the element of intramodal competition has not been considered in the model.

What effect will this simplification have on the interpretation of the results of the analysis? In essence, this simplification of the real world assumes that the individual railroad and trucking company can maintain a relatively fixed portion of the transportation market, when confronted with competition from other railroads and trucking firms. This assumption may be reasonable if the two companies are well established firms. The simplification also assumes, however, that the transportation company, formed from these two firms, faces the same relative demand pattern as the two firms when they were operating singly. This may be a tenuous assumption. There is, however, no means of testing its validity short of actually forming the transportation company in the real world. The reader is left to his own conclusion on the validity of this assumption. The effect of the non-validity of this assumption would be to increase (or decrease) the economic impact transportation companies would have depending upon whether the formation of the company increased (or decreased) the market shares of the combining firms.

Data Realism

> The specification of values for the various parametric characteristics, the second hierarchial level of realism, is also a more difficult problem in simulation of hypothetical companies. ...The currently suggested techniques for generating input data are based upon the assumption that the values can be determined from the analysis of real-world data.[3]

This has been the approach used in this study. Care was taken to use approximate industry average data for the costing of movements. As pointed out by Chervany, however, another criterion that should be used for data generation is that the numerical values used be internally consistent. "This means that the absolute level of the numerical data, while important, is not as important as the interrelationships among the components of this numerical data set".[4] Thus care was taken in this study to use data which was internally consistent, that is the relationships of rail operating ratios, load factors, and so forth, to truck operating ratios, load factors, and so forth, are in the relative proportions that they would be found in the real world.

The Output of the Simulation

The simulation model being studied was constructed to determine the resultant economic impact a transportation company would have and if this impact would be substantially different than the two single modal companies of which it is comprized. Each run of the

[3] Ibid., p. 149.

[4] Ibid., p. 150.

simulation generates a number of statistics for each carrier--the transportation company, the railroad, and the trucker--that are a function of how each carrier prices his services and allocates his equipment. Each run indicates, for instance, the rate at which each carrier decides to price his services consistent with the rate making scheme outlined in Chapter   for each route segment as well as the specific capacity allocations each carrier makes on each route segment. Although such detailed information may be necessary to explain why a certain factor has a significant bearing on the results, it is much too detailed for any type of logical presentation. A number of summary statistics have therefore been developed to aid in the presentation of the results of the study. The remainder of this section shall present these summary statistics or performance measures.

There are probably an infinite number of performance measures one could devise to measure such a nebulous a thing as the economic impact or economic consequences of operating a transportation company under two different organizational approaches. There are two basic dimensions to the problem of measuring the economic impact a transportation company or the single modal carriers create. One should attempt to find measures which indicate how the operations of such companies affect themselves internally as well as how they affect their users. With this in mind the following three performance measures will be utilized to analyze the results of the simulation runs; expected contribution of the carriers, [illegible] of the carriers, and the total price paid for the transportation [illegible].

The nature of the simulation provides a unique opportunity to determine the effect the creation of a transportation company would have on the manner in which movements would take place vis-à-vis single modal carriers. Therefore three statistics have been compiled to indicate whether or not a transportation company would make movements which were significantly different than the manner in which single modal companies make movements in concert. These three statistics are the number of Cwts. moved by truck, amount of Cwts. moved by piggyback, and the amount of Cwts. moved by rail boxcar. These performance measures will be kept for the transportation company, the railroad and the trucking company.

Expected Contribution

There is an additional element of competition present when two single modal companies attempt to obtain a portion of the competitive traffic which a transportation company eliminates. The single modal companies must not only cope with the problem of estimating the size of the market subject to competition but must also estimate what proportion of this market they can obtain. Their estimates of the proportion of the market they can obtain for a particular segment is directly related to the amount of capacity they will allocate to that segment. This is so, because [illegible] will allocate their equipment to maximize their expected contribution to fixed and/or common costs and profit margins. Thus the single modal carriers have an additional element of uncertainty to cope with that a transportation company does not.

A transportation company must only estimate the size of the market, then attempts to allocate to that market the most profitable method of movement. It therefore appears that the expected contribution of the carriers should be examined for effects of the factors since this has a direct bearing on the allocation of equipment and correspondingly on the actual contribution of the carriers.

Actual Contribution

Actual contribution or total contribution of the carriers is probably the most important performance measure which reflects the internal valu f the organizational form. This measure is of extreme impor e if one is trying to examine the merit of establishing transportation companies. Thus the effects the factors have on actual contribution is at the heart of the study. The actual contribution the single modal carriers enjoy is affected not only by shippers' logistics constraints, as is the transportation company contribution, but in addition is affected by the shippers' modal selection policy. Since the competitive market could be allocated equipment from both single modal companies, the shippers' must choose the modes to use which of course affects carrier contributions.

Price Paid for Transportation Services by Users

The price paid for transportation services by users should indicate to some extent, the economic cost of the transportation company versus the single modal carrier organizational approaches.

This performance measure is probably the most important external indicator of the economic value a transportation company would have for its users. Thus the study hopes to indicate which combination of factors, if any, would significantly affect the price paid for transportation services under each of the organizational patterns.

The total price paid for transportation services is a function of the demand for transportation services and the rate charged by carriers. More specifically, the total price paid for transportation by shippers = $\sum_{i}\sum_{j}\sum_{k} X_{ijk} r_{ijk}$;

where,

X_{ijk} = the amount of Cwt. moved by mode i between j and k

r_{ijk} = the rate/Cwt. for mode i between j and k.

It is important to stress the relationship of the price paid to both the amount of Cwt. moved and the rate/Cwt. In other words, the total price paid may increase if one organizational form satisfies more demand than the other. An increase in total price paid could also occur if the rate (price/unit) increases. Conversely, a decrease in total price paid by one organizational form, can occur if less demand is satisfied or if the rate (price/unit) decreases more than the other organizational approach. Thus one cannot tell by inspection whether an increase in price paid resulted from an increase on the rate or because more demand was satisfied either by the transportation company or the single modal companies. The converse is true for a decrease in total price paid. Because of this relationship special care will be taken in the discussion of the results to indicate which of the two variables created the increase (decrease) in the price paid performance measure.

Amount of Trucking Movements

One of the arguments put forth against forming transportation companies is that a transportation company would be dominated by the rail mode with a tendency therefore to drive independent truckers out of business. This study offers the opportunity to observe how a transportation company would allocate movements to its composite modes. The criterion for modal selection within the company when not constrained by shippers' logistics systems is profit (contribution) maximization. It will, therefore, be very interesting to determine if a transportation company moves a significantly different amount of goods by truck than the single modal trucker.

Amount of Piggyback Movements

This statistic is being tested for significance for the same reason as the last measure. In particular, it is directed at determining if the organizational approach has a significant effect on the amount of goods moved by piggyback. It should also be pointed out that this analysis carried to its logical conclusion should provide the answers to what is the optimal equipment mix for a transportation company as well as for single modal carriers.

Amount of Rail Boxcar Movements

The statistic is being tested for significance for the same reasons as the last two measures.

Analytical and Statistical Methodology

In the preceding sections of this chapter, the problems of utilizing a simulation experiment were discussed and the performance measures to be used were presented. Chapter III discussed the test factors which are to be analyzed in the study. This section will introduce the analytical procedure and the statistical tests which will be employed to ascertain the effects the various test factors have on the selected performance measures.

Hypotheses to be Evaluated

This section will present the hypotheses that will be examined in this study, but before doing so a recapitulation of the experimental design developed thus far will be given. The economic performance of each single modal company and the transportation company will be described by six statistics--expected contribution, actual contribution, price paid by users, and the amount of Cwts. moved by truck, piggyback, and by rail. The principle focus of the research will be placed on how the two organizational approaches differ with respect to the performance measures. That is, the analysis of the output of the simulation will be will be concerned with the difference between the transportation company performance measures and the sum of the performance measures of the single modal carriers. For each simulation run which incorporates a different combination of the internal and external route factors, these descriptive statistics will be calculated. The hypotheses which will be tested are concerned with: (1) the mean differences between the performance measures of the transportation company and the single modal carriers, and (2) the effects the combinations of the test factors have on the economic performance of the carriers.

The analysis of the test factors is concerned with whether the test factors "cause" significant changes in the values of the performance measures from their average value. It is also of interest to determine if the mean differences between the organizational approaches are statistically significant. In other words, one is interested in determining if the performance measures of the transportation company are significantly different, on the average, from the sum of the measures of the single modal carriers. The null hypotheses are for each performance measure that the mean of the transportation company and the mean of the sum of the single modal carrier performance measures are the same. The alternative hypotheses are that the means are different. The nature of the output, being that the random components and parametric values were constant across the organizational alternatives, indicated that a t test involving paired differences was appropriate.[5]

Since the analysis of the result is largely concerned with the effects brought about by changes in the levels of the test factors, a much more detailed description of the statistical procedure utilized for this purpose will be presented below.

The analysis will be mainly concerned with: (1) determining if a change in the level of any single test factor has a significant overall effect on the performance measures over all combinations of the other test factors; (2) determining if any combinations of any two test factors has a significant effect on the performance measures.[6] The first type of affect is called a main effect, while the second is referred to as a first-order interaction effect.[7]

They hypotheses which will be tested are concerned with the nature of all of the main effects and first-order interaction

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[5]The nature of the t test which was used is described in detail in Appendix 1. For a discussion on the appropriateness of this particular test, the reader is referred to Guenther, op.cit., p. 24.

[6]The word combination as used above, refers to the number of experimental conditions or possible number of arrangements of the levels of the test factors that are possible in the experimental setting.

[7]There are also second-order, third-order, fourth-order, and fifth-order interaction effects associated with the test factors which will not be analyzed in the project. The nature of the specific experimental design utilized in this study does not provide for the analysis of these effects. The nature and reasons for the selection of the experimental design used in this project will be explained in the next section of this chapter.

effects associated with six of the seven test factors selected for analysis. The test factor which will not be tested for effects is the size of shipments factor. Instead of testing this factor for effects, the entire experiment will be repeated for this factor at each of its two levels. This is because, as explained earlier, the costs of moving CL/TL shipments differ from those involving LTL movements. Also the choice of how the movements are to take place differ for the two sizes of shipments. In the TL/CL shipments, movements may take place by truck, both of the piggyback methods, or by rail, whereas LTL shipments may take place only by truck or by both piggyback methods. In capsule form, the test factors which will be analyzed at each level of the size of shipments factor are (see Table I, Chapter III):

1. High versus low truck operating ratios--An analysis of the effects of a 99% operating ratio vis-á-vis a 91% operating ratio.
2. High versus low rail operating ratios--An analysis of the effects of an 85% operating ratio vis-á-vis a 65% operating ratio.
3. Low versus high truck load factor--An analysis of the effects of an average truck load factor of 100 Cwt. vis-á-vis an average truck load factor of 300 Cwt.
4. Low versus high rail load factor--An analysis of the effects of an average rail load factor of 400 Cwt. vis-á-vis an average rail load factor of 800 Cwt.

5. <u>High versus low system capacity</u>--An analysis of the effects of excess system capacity vis-á-vis adequate system capacity to meet system wide demand.

6. <u>High versus low level of shipp 's' logistics constraints</u>--An analysis of the effects of a system constrained to a large extent by shippers' logistics systems demands vis-á-vis a system constrained very little by shippers' logistics systems.

The null hypotheses which will be tested are that none of the main effects or interaction effects differ from zero. That is, the null hypotheses state that none of the test factors (or combinations of test factors being considered) produce significant differences between the performance measures of the transportation company and the single modal carriers. Rejection of any of these null hypotheses indicates that the specific test factor (or combination of test factors) <u>may</u> have important cause and effect relationships which affect the economic performance of the transportation company vis-á-vis the single modal carriers. Conversely, non-rejection of any of the null hypotheses implies that the specific test factor (or combination of test factors) <u>may not</u> have important cause and effect relationships which affect the economic performance of the transportation company as compared to the single modal carriers.

In the preceding statements the word <u>may</u> has been stressed. This is because it must be emphasized that the results which are obtained pertain to the analysis of the simulation model per se.

That is, the results are obtained from the manipulation of a mathematical model which was formulated to resemble the real world phenomonon. Before the results may be stated as truths research and analysis in the real world is required. The results may stand, however, as working hypotheses until verified or disproven by real world research.

Fractional Factorial Experiments

In light of the preceding discussion, the experimental design chosen for this project must allow for the analysis of the main effects and first-order interaction effects. Factorial experiments allow for such analysis.[8] "A factorial experiment is one in which all levels of a given factor are combined with all levels of every other factor in the experiment."[9]

In this project six test factors (each with two levels) have been selected for analysis for each level of the size of shipment parameter.[10] This may be described as two 2^6 factorial experiments, one for each shipment size. This means for one complete replication of the experiment there are 128 possible combinations of factors for each of the three carriers that must be

[8] For an excellent discussion on the advantages and usefulness of the factorial design for simulation experiments of the nature of this project, see Chervany, *op. cit.*, pp. 246-250.

[9] Charles R. Hicks, *Fundamental Concepts in the Design of Experiments* (New York: Holt, Rinehart, and Winston, Inc., 1964), p. 78.

[10] See Table I, *Supra*, chapter III, p. .

simulated if this complete factorial experiment was run. If additional replications were added to increase the reliability of the results, the number of simulation runs required becomes even larger.

In order to reduce the number of runs required and yet to obtain as much information as possible concerning the main and first-order interaction effects, a one-half fractional factorial design was utilized in this study. A fractional factorial design uses, as the name implies, a fraction of a replicate of a factorial experiment. The one-half fractional factorial design which was used in this project is identified in Table IX.

In this particular design the main effects and the first-order interaction effects are confounded[11] with the higher order interaction effects. The higher order interaction effects with which the main and first-order interaction effects are confounded are referred to as the aliases of the main and first-order interaction effects.[12] Thus, in effect, if one of the null hypotheses is

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[11] Effects are confounded with one another when the same data and estimator of the effects are used to determine those (both) effects. (William Mendenhall, The Design and Analysis of Experiments (Belmont, California: Wadsworth Publishing Company, Inc., 1968), p. 312.

[12] In the design used in this study each main effect and first-order interaction effect is confounded with one higher order interaction effect. The defining contrast, which indicates which effects are confounded, for this design is ABCDEF. To determine the alias of an effect one would multiply the defining contrast by the effect of interest, dropping the squared terms. For instance the alias of the AB effect is the [AB(ABCDEF) =] CDEF effect.

TABLE IX[13]

ONE-HALF FRACTIONAL FACTORIAL DESIGN

(1)	ab	ac	bc
abcd	cd	bd	ad
bcef	acef	abef	ef
adef	bdef	cdef	abcdef
abce	ce	be	ae
de	abde	acde	bcde
af	bf	cf	abcf
bcdf	acdf	abdf	df

rejected one would not know which of the effects (the alias or the effect of interest) caused the rejection. In order to circumvent this difficulty, the higher order effects will be assumed to be zero. If the reader has some doubt about the validity of this assumption, the results of this study will have (for him) at least, narrowed the causative factor to the proper alias group.[14]

[13] The appearance of a small letter in the table means a factor is present at the second (alternate) level. The absence of a letter means a factor is at the first (standard) level. (1) signifies all factors are at the first level.

[14] For a much more detailed discussion of the concepts discussed in this section, the reader is referred to Chervany, op.cit., pp. 248-257.

Statistical Analysis

The mathematical model of the fractional factorial design used in this study is presented below:[15]

$$(1) \quad X_{ijklmn} = \mu + A_i + B_j + C_k + D_l + E_m + F_n + AB_{ij} + AC_{ik} + AD_{il} + AE_{im} + AF_{in} + BC_{jk} + BD_{jl} + BE_{jm} + BF_{jn} + CD_{kl} + CE_{km} + CF_{kn} + DE_{lm} + DF_{ln} + EF_{mn} + \epsilon_{ijklmn}$$

where

X_{ijklmn} = the observation of the performance measure for a given run

μ = the mean observation of the performance measure from all runs

$A_i, \ldots, F_n$ = main effects of the factors

$AB_{ij}, \ldots, EF_{mn}$ = first-order interaction effects of the test factors

ϵ_{ijklmn} = unexplained variation of the observation of a particular run (error term)

i, j, k, l, m, n = 1 if the observation was generated from a run in which the test factor was at level 1 or 2 if the test factor was at level 2.

[15] Hicks, op. cit., pp. 221-231.

The major focus of this research project will deal with the statistical tests (and corresponding explanation) of the null hypotheses presented in a previous section of this chapter. The tests will be conducted to determine if the difference between the performance measures of the organizational approaches are significantly different from zero. The analysis of variance (ANOVA) technique will be employed to determine if the differences in the measures are significant.

Since the test factors and their corresponding levels were preselected by the author for analysis, the fixed-effects analysis of variance model is the appropriate statistical technique which will be used to analyze the effects of interest.[16] To utilize this technique the following assumptions are necessary:

1. The error terms, ε_{ijklmn}, are independently normally distributed with a mean of zero and a constant variance σ^2.[17]
2. The effects are additive.[18]
3. The aliases of the main and first-order interaction effects are zero.[19]

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[16] Guenther, op.cit., p. 37. There is another ANOVA model which is appropriate when the factors are selected at random. It is referred to as the random effects model.

[17] Ibid., p. 36.

[18] Chervany, op.cit., p. 260.

[19] This assumption was discussed in the previous section of this Chapter.

What impact would the non-validity of these assumptions have on the analysis? If the "true" model of the experiment is not additive the size of the error variance will increase which would lead to less significant results being reported than is actually the case.[20] The author has no reason to believe that the "true" model would not be additive however.

The remaining discussion will focus on the assumptions concerning the error terms.

> ...studies have indicated that inequality of variances does not seriously affect the F-test [the test statistic utilized in the analysis of variance] ... if the sample sizes are equal [which is the case in this project].
>
> A further assumption we made in discussing the analysis of variance techniques was normality of the observations. Although the test is derived under this assumption, investigation has shown that failure to satisfy this condition has little effect upon the F-test. ...
>
> We should make every possible effort to obtain independent random samples. Nonrandomness can very seriously affect the conclusions we draw from an experiment.[21]

Thus the most critical assumption in the analysis of variance technique centers on the independence of the samples (runs).

Because the summary statistics used in the study are differences between the organizational forms, the same set random numbers were used to compare the transportation company with the single modal companies in a given run. This should act to sharpen the contrast between the two approaches. Yet, to insure the independence of

[20] Chervany, op.cit., p. 263.

[21] Guenther, op.cit., p. 63.

observations between runs, a different set of random numbers was utilized for each run to determine the random components of the model.[22]

[22] For a more detailed discussion on the material presented in this section, the reader is referred to Chervany, *op.cit.*, pp. 257-266.

CHAPTER V

RESULTS OF THE SIMULATION ANALYSIS

The nature and intent of this project has been described in the previous four chapters. Chapter I presented the background and described the nature of the research effort. The simulation model was presented in Chapter II. The test factors and costing data were described in Chapter III. The last chapter outlined the experimental design which was used to analyze the results of the simulation.

This chapter discusses the results of the simulation. Attention will be focused on the effects upon the performance measures produced by the various test factors. The analysis will be concerned with describing the nature of the effects and discussing the model operations which caused them. The implications of the results for the real world will be reserved for the final chapter.

Nature of the Analysis

As previously stated, the purpose of this dissertation is to determine the effects the selected test factors have on the economic consequences resulting from the formation of transportation companies vis-à-vis single modal carriers. Therefore, the principal focus of the results of the research will be placed on how the two organizational approaches differ with respect to the performance measures. That is, the analysis of variance that is being used to statistically analyze the output of the simulation will be concerned with the difference between the transportation company performance measures and the sum of the performance measures of the single modal carriers. More specifically, the summary statistics which will be analyzed are the performance measures of the transportation company minus the performance measures of each single modal company. An example should help to clarify this measurement approach. Suppose that on a given simulation run the actual contribution of the transportation company was $224,000.00 as compared to $163,000.00 for the railroad and $52,000.00 for the trucker. The statistic which would be entered into analysis of variance calculations would be $224,000.00 - ($163,000.00 + $52,000.00) = $9,000.00.

In order to determine if these differences are statistically significant, a standard of comparison is required. The analysis of variance technique, that is being utilized to analyze the results, measures the effects of the test factors in terms of deviations from the mean of the performance measure in question. In other words, the standard of comparison used in this study is the average of the differences of the performance measures between the transportation company and the single modal carriers. The discussion of the results will describe the mechanisms which caused the effects.

As mentioned in Chapter IV, 64 different simulation runs were required to measure the effects. The analysis concentrates upon the differences, between the organizational approaches, of the six performance measures: (1) expected contribution, (2) actual contribution, (3) price paid, (4) amount of truck movements, (5) amount of piggyback movements; and (6) the amount of rail movements. For each of the simulation runs these statistics were gathered.

It was also mentioned in the last chapter that the mean difference between the performance measures of the transportation company and the single modal carriers would be tested for significance. In other words, the results of this type of a test would indicate if there is an appreciable difference between the performance measures "on the average". In order to obtain the average difference in performance measures between the organizational alternatives the above six measures were averaged over the simulation runs. The average differences for each level of the size of shipment parameter are presented in Table Xa.

Explanation of the Average Performance Measures

Some explanation of how to interpret the average performance measures is necessary, but before beginning this discussion the relationships between the performance measures will be recapitulated. The expected contribution of the carriers is a projection made by the carriers based upon their forecast of the total market for transportation for each route segment and their forecast of their market share. The actual contribution of the carriers is based upon how they allocate equipment to the various segments, the accuracy of their forecasts, the shippers' modal selection policy as well as carrier pricing decisions. The price paid by shippers for transportation services is a function of the shippers' modal selection policy, the demand for transportation, the carriers pricing and equipment allocation decisions. The amount of truck, piggyback, and rail movements are dependent upon the pricing and equipment allocation decisions of the carriers as well as the shippers' modal selection policy and market demand.

The first three performance measures--expected contribution, actual contribution, and price paid--are directly concerned with the economic impact the two organizational alternatives have on the carriers and users of transportation. The latter three measures--amount of Cwt. moved by truck, piggyback, and rail--are determinants of the first three measures. In other words, the expected and actual amount of Cwts. moved by each method of movement determines the expected and actual contribution of the carriers and the price paid for transportation by users. For instance, the actual contribution obtained by the carriers is dependent upon the amount of piggyback, truck, and/or rail movements that take place. These interdependencies between the performance measures will aid in the explanation of the cause and effect relationships between test factors and significant performance measures.

As indicated in the last chapter a t test was utilized to determine if the mean differences in the performance measures between the organizational approaches were statistically significant.[1] The results of the test are indicated by the use of asterisks in Table Xa. One asterisk (*) indicates the hypothesis is significant at the 10% level. That is, one asterisk means the null hypothesis is not accepted (rejected) with the probability of 10% that the null hypothesis is in fact true (Type I statistical error). Two asterisks (**) indicate significance at the 5% level. Three asterisks (***) indicate the results are significant at the 1% level.[2]

As can be seen in Table X, the differences between the means of the transportation company's performance measures and those of the combined single modal carriers are in most cases significant. Table Xb presents the relative differences in performance measures between the transportation company and the single modal carriers. For instance in the TL/CL market, the transportation company made 44% fewer piggyback movements than did the single modal carriers.

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[1] *Supra*, chapter iv, p. 98.

[2] These significance levels are appropriate for a single test, when one conducts multiple tests the probability of falsely rejecting at least one true null hypothesis is [1 - p (not rejecting on all the tests)]. See, for example, Mendenhall, *op. cit.*, p. 175.

TABLE X

a: AVERAGE DIFFERENCES OF THE PERFORMANCE MEASURES BETWEEN THE TRANSPORTATION COMPANY AND THE SINGLE MODAL CARRIERS

	TL/CL Movements	LTL Movements
Expected Contribution	$24,221.53***	$ 18,158.30*
Actual Contribution	$23,143.72***	$ 17,513.62*
Price Paid	7,662.38	- 92,475.94***
Truck Movements	- 7,481 Cwt.	-101,650 Cwt.***
Piggyback Movements	-49,331 Cwt.**	91,306 Cwt.***
Rail Movements	70,388 Cwt.***	----

*Significant at the 10% level

**Significant at the 5% level

***Significant at the 1% level

TABLE X

b: THE AVERAGE DIFFERENCES AS A PERCENTAGE INCREASE (+) OR DECREASE (-) OF THE COMBINED SINGLE MODAL PERFORMANCE MEASURES

	TL/CL Movements	LTL Movements
Expected Contribution	+11%[3]	+17%
Actual Contribution	+11%	+16%
Price Paid	+ 1%	-12%
Truck Movements	- 4%	-35%
Piggyback Movements	-44%	----[4]
Rail Movements	+24%	----

As indicated in Table X, one may conclude the expected contribution and the actual contribution of the transportation company is larger than the single modal carriers, although at different levels of significance. The price paid by shippers is significantly less for LTL movements when transported by the transportation company. The price paid for services was not significantly different between the two approaches for TL/CL movements. In the LTL category, the transportation company moved less goods by truck and more by piggyback, which contributed both to the higher contribution and reduction in

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[3]The figures in this table represent the ratio of the average differences in performance measures (Table Xa) to the average combined single modal performance measures, e.g., $\frac{24,221.53}{202,218.63} = +11\%$.

[4]There were no single modal piggyback movements in LTL freight. The increase in Cwt. moved by piggyback in the transportation company setting was 91.306 Cwt.

price paid by shippers. In the TL/CL category of movement, the transportation company made more movements by rail and fewer by piggyback than did the single modal carriers. In general, this occurred because the single modal trucker participated in Plan I moves when he was not the low cost carrier. In a large number of cases when this occurred, the rail mode was low cost but Plan I was competitive. Hence the transportation company shifted Plan I moves to rail in those cases, which of course, effected contribution and price. Other factors played an important role on the performance measures which will be explained in great detail in the next section of this chapter.

To reiterate, the figures in Table Xa represent the average differences between the transportation company performance measures and those of the railroad and trucker. For instance, in the TL/CL category of movements, the transportation company had generated $23,143.72 on the average more contribution than the railroad and trucking companies. In the same manner, in the LTL category of movements, the transportation company moved 101,650 Cwt. of product less by truck than did the single modal carriers (the trucker).

It should also be pointed out that the differences between the amount of truck movements, in the LTL category, is not completely made up by piggyback movements. In other words, the transportation company moves 101,650 Cwt. less by truck than the single modal carriers, but shifts only 91,306 Cwt. to piggyback movements. On the other hand, in the TL/CL category, the fewer truck load and piggyback movements are more than compensated for by rail movements.

Why is this so? In the TL/CL situation many factors may contribute to this effect. For instance, there were situations on some route segments where the trucker was not the low cost carrier but could compete for traffic. If the trucker exhausted his equipment capacity on other route segments, in the single modal setting, demand for service was unmet on some route segments. The transportation company, on the other hand, if it had rail capacity could substitute this service if not constrainted. Thus, the differences in the amount of movement by each mode need not sum to zero. Similar considerations come into play in the LTL category of movement.

The LTL category of movement, however, does have a unique situation which must be discussed. In the model, the single modal trucker really has no competition for LTL movements. This is the same as saying the model is considering only that LTL portion of the market which moves by common carrier truck. At any rate, the trucker and the railroad do not have to participate in Plan I piggyback movements. If they do participate, they will split the profit contribution on the basis of cost contributions as explained in Chapter III. Since the trucker has no real competition for LTL traffic, he will set his LTL rate at his full costs, consistent with the pricing policy established in Chapter II. Thus, in LTL movements the single modal trucker is not likely to participate in Plan I movements.

In the case of TL/CL movements, the full cost of the low cost mode will govern the action of the single modal trucker. If Plan II piggyback or the rail mode is low cost, the trucker may wish to participate in Plan I movements to obtain some share of the competitive market.

Regardless, the transportation company will establish the rate at the full cost of the low cost mode. In the case of LTL movements either at the trucking full costs or the piggyback full costs whichever is lowest for a given route segment. Thus in the single modal LTL market segment, the product will be moved at the full costs of the trucker, while the transportation company will price its services at the full cost of the low cost method.[5] In a large number of cases, the full cost of piggyback movements were lower than the full costs of truck movements. This is what creates the large difference in price paid for transportation services in the LTL category between the transportation company and the single modal carriers, as shown in Table X. Furthermore, the rail flatcar capacity was the limiting resource of the transportation company. Because the transportation company was pricing services at the full cost of the low cost mode, some trucking movements

[5] In practice it may be more likely that the transportation company would price its services in the LTL market at the trucker's full costs. The pricing policy would depend upon how the I.C.C. would react to the transportation company pricing its services in the LTL market at its full costs. If the transportation company did price at the trucker's full costs, the difference between the expected and actual contributions of the organizational forms would become even larger than that in Table X.

were not attractive even after all the flatcar capacity had been exhausted. This accounts for the differences between the amount of trucking movements not being fully compensated for by piggyback movements for LTL movements in Table X.

Analysis of the Test Factors

Before proceeding with the analysis of the test factors, the symbolic representations of the test factors will be recapitulated. The symbols which are associated with each test factor are displayed in Table XI.[6]

TABLE XI

TEST FACTOR SYMBOLS

A	Truck Operating Ratio
B	Rail Operating Ratio
C	Truck Load Factor
D	Rail Load Factor
E	System Capacity
F	Shippers' Logistics Constraints

This section presents the analysis of the effects produced by the six test factors, for each level of the size of shipments parameter, on each of the performance measures. The analysis will be composed of two parts. First the effects which are found to be statistically significant will be identified. Secondly, an

[6] For detail concerning the levels of the test factors, the reader is referred to Table I, Chapter III, *Supra.*, p. 64.

explanation of what "caused" the factor to be significant in terms of the manner in which the model operated will be given. One cannot be absolutely sure, however, that the explanations will be complete or accurate. This is because of the complexity of the interactions of the system which required simulation to be used as a methodology to study the transportation company concept.

As indicated in the last chapter, the main effects and interaction effects will be tested for significance. The main effects and interaction effects are numerical measures of each type of effect. "In general, an effect is the average difference between observations (of a particular performance measure) generated from simulation runs where a test factor is at its alternate level, and the observations where a test factor is at its standard level".[7] The effects are defined mathematically as follows:[8]

1. MAIN EFFECT:

$$ME_j = \sum_{i=1}^{n_j} \frac{X_{ij}}{n_j} - \sum_{i=1}^{n} \frac{X_i}{n} \qquad (j = 1, \ldots, 6)$$

where:

ME_j = main effect of the jth test factor

X_{ij} = ith observed measure when the jth test factor is at its alternate level,

X_i = ith observed measure when the jth test factor is at its standard level,

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[7] Chervany, op.cit., p. 272.

[8] Ibid., p. 273.

n_j = the number of observations when the jth test factor is at its alternate level, and

n = the number of observations when the jth test factor is at its standard level.

2. FIRST-ORDER INTERACTION EFFECTS:

$$IE_{j_1j_2} = \frac{1}{2}\left[\left(\sum_{i=1}^{n_{j_1j_2}} \frac{X_{ij_1j_2}}{n_{j_1j_2}} - \sum_{i=1}^{n_{j_2}} \frac{X_{ij_2}}{n_{j_2}}\right) - \left(\sum_{i=1}^{n_{j_1}} \frac{X_{ij_1}}{n_{j_1}} - \sum_{i=1}^{n} \frac{X_i}{n}\right)\right]$$

$(j_1 = 1, \ldots, 6)$
$(j_2 = 1, \ldots, 6)$
$(j_1 \neq j_2)$

where:

$IE_{j_1j_2}$ = first-order interaction effect of the j_1th and j_2th test factors,

$X_{ij_1j_2}$ = ith observed measure when the two test factors (j_1 and j_2) are both at their alternate levels,

X_{ij_2} = ith observed measure when test factor j_1 is at its standard level and test factor j_2 is at its alternate level,

X_{ij_1} = ith observed measure when test factor j_1 is at its alternate level and test factor j_2 is at its standard level,

X_i = ith observed measure when both test factors (j_1 and j_2) are at their standard levels,

$n_{j_1 j_2}$ = the number of observations when the two test factors (j_1 and j_2) are both at their alternate levels,

n_{j_2} = the number of observations when test factor j_1 is at its standard level and test factor j_2 is at its alternate level,

n_{j_1} = the number of observations when test factor j_1 is at its alternate level and test factor j_2 is at its standard level, and

n = the number of observations when both test factors (j_1 and j_2) are at their standard levels.

An example should help to clarify how the measurement calculations are made. From Table X the difference between the expected contribution of the transportation company and the expected contribution of the single modal carriers is $24,221.53 for TL/CL movements. The average difference between the expected contribution when the truck operating ratio was at its alternative level, i.e., 91% was 24,169.67. Similarly, when the truck operating ratio was at its standard level, i.e., 99%, the average difference in expected contribution between the organizational alternatives was 24,273.39. The difference between these averages ($103.72) is the main effect of the low operating ratio (91%) over the high operating ratio (99%).

The operational interpretation of the interaction effects is much the same. For example, the interaction effect of truck operating ratio and system capacity (AE interaction, see Table XIIa) resulted in an increase in the difference between the expected contribution of the transportation company as compared to the single modal carriers of $8883.32. This represents the average of the expected contribution when both factors, A and E, were at their standard levels plus the average when both factors were at their alternate levels minus the averages when one factor was high and the other factor low.

Before proceeding with the analysis, the direction of the change in the economic performance measures brought about by changes in the levels of test factors deserves some discussion. An increase in the expected and actual contribution indicates that the transportation company is more "profitable" than the single modal carriers. A decrease in thses performance measures indicates under what circumstances (test factor levels) the single modal carriers may economically out perform the transportation company. Similarly, an increase in price paid would mean the single modal carriers were more economical to users than a transportation company. Conversely, a decrease in the price paid for transportation, indicates the transportation company may be more economical to users than single modal competitive carriers.

The effects of the test factors are summarized in Tables XIIa through XVIIb. The results of the analysis of variance are identified by the use of asterisks as described earlier in this chapter.

Effects of a Change in Truck Operating Ratio (99%-91%) on the Performance Measures

The effects of the change in truck operating ratios are presented in Tables XIIa and XIIb. These results indicate that no significant change in the performance measures occurred due to changes in this factor. The lone exception to the lack of significant effects took place in the amount of rail movement measure in the TL/CL category of movements. The interaction of a decrease in truck operating ratio with a reduction in system capacity caused more movements to take place by rail boxcar. The reason for this result is that the change in truck operating ratio did cause more movements to take place by truck, although not a significant amount, by shifting piggyback movements to the trucking mode. When the trucking mode capacity was restricted, the transportation company would in general, when not constrained, shift trucking moves to rail moves, especially on the longer route segments where the rail mode even if not low cost made a substantial contribution to profit and fixed and/or common costs.

TABLE XIIa: EFFECTS OF A CHANGE IN TRUCK OPERATING RATIO ON THE TL, CL PERFORMANCE MEASURES

EFFECTS:	1. On Expected Contribution	2. On Actual Contribution	3. On Price Paid	4. On The Amount Of Truck Movements	5. On The Amount Of Piggyback Movements	6. On The Amount of Rail Movements
MAIN EFFECT A ([illegible])	- 103.72	128.45	1308.00	5888	- 9113	525
INTERACTION EFFECTS						
B	-3303.52	-2458.95	4099.50	-9038	18338	1950
C	7.84	345.83	1538.25	7913	- 2963	-17775
D	- 948.85	- 116.12	-11934.25	-8888	- 5663	1650
E	8883.32	8319.89	1166.75	15498	-26588	26175*
F	-1067.69	-2162.66	3360.50	8813	- 1988	- 2025

*Significant at the 10% level

**Significant at the 5% level

***Significant at the 1% level

TABLE XIIb: EFFECTS OF A CHANGE IN TRUCK OPERATING RATIO ON THE LTL PERFORMANCE MEASURES

EFFECTS:	1. On Expected Contribution	2. On Actual Contribution	3. On Price Paid	4. On The Amount Of Truck Movements	5. On The Amount Of Piggyback Movements
MAIN EFFECT A ([illegible])	-16377.16	-16354.87	$25058.75	6325	- 1788
INTERACTION EFFECTS					
B	- 8363.33	- 7714.15	- 9705.38	- 3400	2888
C	8691.20	9162.36	- 23176.88	-21075	13388
D	1938.40	2465.07	22503.75	- 3088	7625
E	11475.65	11886.35	22028.38	9613	- 3725
F	-10859.[illegible]	-10837.74	19742.50	23500	-16113

*Significant at the 10% level

**Significant at the 5% level

***Significant at the 1% level

Effects of a Change in Rail Operating Ratio (85%-65% on the Performance Measures

The effects of the change in rail operating ratios are presented in Table XIIIa and XIIIb. There are a number of statistically significant results in all the performance measures except on the amount of truck movements.

Expected Contribution--In both the TL/CL and LTL categories of movement, the reduction in rail operating ratio caused a significant increase in the expected contribution of the transportation company as compared to the single modal companies. There was also a significant interaction of a decrease in rail operating ratio with an increase in rail load factor in the TL/CL movement category. This interaction (BD) had the effect of lowering the expected contribution of the transportation company vis-á-vis the single modal companies.

Actual Contribution--Again for both TL/CL and LTL movements, the reduction of rail operating ratio caused a significant increase in the actual contribution of the transportation company as compared to the single modal carriers. There was also a significant interaction of a decrease in rail operating ratio with an increase in rail load factor (BD) in the TL/CL movement category. As one might expect, this interaction had the same effect on actual contribution as it did on expected contribution; that is, it caused a lowering of the actual contribution of the transportation company vis-á-vis the single modal carriers.

TABLE XIIIa: EFFECTS OF A CHANGE IN RAIL OPERATING RATIO ON THE TL, CL PERFORMANCE MEASURES

EFFECTS:	1. On Expected Contribution	2. On Actual Contribution	3. On Price Paid	4. On The Amount Of Truck Movements	5. On The Amount Of Piggyback Movements	6. On The Amount Of Rail Movements
MAIN EFFECT B (???)	17633.82**	17,486.87**	-16269.75**	- 8138	-27563*	27600*
INTERACTION EFFECTS						
A	- 3303.52	- 2458.95	4099.50	- 9038	18338	1950
C	- 9938.37	- 9530.04	-17113.50**	-15413	-10163	4950
D	-18116.80**	-17391.69**	- 6890.00	8738	27487	-30825**
E	- 5178.44	- 5203.52	- 5346.00	- 7988	26513	-19350
F	11358.43	11187.30	- 3568.75	- 8362	- 9938	17700

*Significant at the 10% level.

**Significant at the 5% level.

***Significant at the 1% level.

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TABLE XIIIb: EFFECTS OF A CHANGE IN RAIL OPERATING RATIO ON THE LTL PERFORMANCE MEASURES

EFFECTS:	1. On Expected Contribution	2. On Actual Contribution	3. On Price Paid	4. On The Amount Of Truck Movements	5. On The Amount Of Piggyback Movements
MAIN EFFECT B (5 - 6)	21591.49*	21448.35*	-26843.00	-26700	17512
INTERACTION EFFECTS					
A	- 8363.33	- 7714.15	- 9705.38	- 3400	2888
C	-11870.22	-11972.08	19867.13	- 9325	12363
D	- 8329.47	- 8319.84	-24855.25	-21338	12150
E	- 8638.26	- 8484.32	-12578.83	17288	-22125
F	11355.22	12028.06	-26597.25	- 1275	- 5063

* Significant at the 10% level.
** Significant at the 5% level.
*** Significant at the 1% level.

<u>Price Paid</u>--The change in rail operating ratios caused a significant reduction in the price paid for transportation services for users of the transportation company vis-á-vis the single modal carriers in the TL/CL category of movements. This factor had no effect on the price paid for LTL movements. There was one significant interaction with the truck load factor (BC) in this performance measure for LTL movements. This interaction, a reduction in rail operating ratio and an increase in truck load factor had the effect of lowering the price of service for the users of the transportation company as compared to the single modal carriers.

<u>Amount of Piggyback Movements</u>--The reduction in rail operating ratio caused a significantly fewer amount of piggyback movements to take place in the transportation company setting than in the single modal carrier environment for TL/CL movements. There was no significant difference between the systems as far as LTL movements are concerned.

<u>Amount of Rail Movements</u>--The fewer piggyback movements were compensated by a larger amount of rail movements in the TL/CL category. There are, of course, no [illegible] movements being considered in the LTL category. The reduction of rail operating ratio combined with an increase in rail load factor produced a significant interaction (BE) which had the effect of reducing the number of rail movements.

__Explanations__--What interrelationships within the simulated system caused these changes in the performance measures? To begin the discussion, it was pointed out that the transportation company experienced larger expected and actual contributions in both categories of movement than did the single modal companies with a reduction in the rail operating ratio. The reasons for the increased profit contribution of the transportation company over the single modal companies are the same in both cases. The transportation company shifted traffic from truck and piggyback to rail movements. It did this to the extent possible. That is, the transportation company shifted as much traffic to the rail mode, which the single modal companies were moving by rail and piggyback, as it could without violating shippers' logistics constraints and capacity constraints.

The significant interaction effects under expected contribution and actual contribution, BD, indicates that the combination of a low rail operating ratio and a high rail load factor significantly reduced the expected and actual contribution of a transportation company as compared to its single modal counterparts. It must be remembered, however, that these results must be interpreted in conjunction with the results displayed in Table X. It can be seen that the BD interaction is negative in each case. Thus, the BD interaction effect is to lower the figure of the expected and actual contribution in Table X. The reason the BD interaction is negative is that this combination is the most favorable rail position for single modal carriers. Thus the formation of a transportation company with these rail characteristics while still improving the profit situation of the transportation company over the single modal carriers does not result in as large an increase as the average presented in Table X.

The effect of a reduction in rail operating ratio was to reduce the difference in total price paid for transportation by users between the organizational approaches. The reduction in rail operating ratio made the rail mode in both organizational settings the most "profitable" method of movement on a large number of route segments. Also, the reduction in rail operating ratio made the rail mode much more competitive with the independent trucker. In other words, on some route segments when the rail mode had a high operating ratio the only traffic it could obtain was that reserved for the mode due to shippers' logistics constraints. On other route segments the rail carrier would attempt to compete with Plan II movements. Under these circumstances the single modal trucker, in a number of situations, would exhaust his capacity before demand was satisfied. The transportation company, on the other hand, because it controlled both modes made different allocation decisions (based upon total system wide contribution ("profit") maximization) which resulted in more demand being satisfied. Because more demand was satisfied, the corresponding total price paid for service was greater for the transportation company that the single modal carriers, when the rail mode had a high operating ratio. Thus the reduction in rail operating ratio, since it enabled the single modal rail carrier to be more competitive, reduced the difference in the price paid between the transportation company and the single modal carriers. In fact, on a large number of runs, where the rail operating ratio was at its low level, the difference in price paid between the two alternative organizational approaches was zero. Thus, the overall effect of a reduction in rail operating ratio was to increase the contribution of the transportation company over that of the single modal carriers at substantially the same price to users as that paid to the single modal companies.

The interaction of a reduction in rail operating ratio and an increase in truck load factor (BC) had much the same effect as that described in the last paragraph. The increase in truck load factor coupled with a reduction in rail operating ratio made piggyback movements, in general, the dominant method of movement in both organizational settings. Hence, the difference in price paid for transportation services between the organizational alternatives was very much closer together than when the truck load factor was at its low level. In other words, the difference in price paid for services between the organizational alternatives under these circumstances (factor levels) was zero or nearly zero in all cases, as opposed to situations when these factors were at their standard levels.

Effects of a Change in Truck Load Factor (100 Cwt.-300 Cwt.) on the Performance Measures

The effects of the change in truck load factor from 100 Cwt. to 300 Cwt. are presented in Table XIVa and XIVb. The change in this factor produced several statistically significant results.

Expected Contribution--The increase in the truck load factor significantly reduced the expected contribution of the transportation company vis-á-vis the single modal companies in the LTL category of movements. This factor had no significant effect on expected contributions for CL/TL movements. There were two significant interaction effects for this measure. The CD interaction effect, increased truck load factor with low system capacity, was to significantly increase the expected contribution of the transportation company vis-á-vis the single modal carriers. The same kind of effect was caused by the CD interaction effect, high truck load factor with high rail load factor.

Actual Contribution--The change in truck load factor produced no significant main effects in this performance measure. There were two significant interaction effects however. Again for the TL/CL movements, the interaction effect with system capacity (CE) was to increase the actual contribution. This same kind of reaction was produced by the interaction effect with rail load factor (CD) in LTL movements.

TABLE XIVa: EFFECTS OF A CHANGE IN TRUCK LOAD FACTOR ON THE TL, CL PERFORMANCE MEASURE

EFFECTS:	1. On Expected Contribution	2. On Actual Contribution	3. On Price Paid	4. On The Amount Of Truck Movements	5. On The Amount Of Piggyback Movements	6. On The Amount Of Rail Movements
MAIN EFFECT C (. 0 Cwt.-200 Cwt.)	- 3112.16	- 2980.96	14328.00*	4763	29738*	-15225
INTERACTION EFFECTS						
A	7.84	345.83	1538.25	7913	- 2963	-17775
B	- 9938.37	- 9530.04	-17113.50**	-15413	-10163	4950
D	1493.65	1734.12	2476.25	- 7763	- 3263	15150
E	14201.20*	13276.18*	17726.25**	17063	-30338*	13725
F	874.39	114.37	13872.50*	- 8063	24563	- 5175

*Significant at the 10% level.

**Significant at the 5% level.

***Significant at the 1% level.

TABLE XIVb: EFFECTS OF A CHANGE IN TRUCK LOAD FACTOR ON THE LTL PERFORMANCE MEASURES

[illegible]	1. On Expected Contribution	2. On Actual Contribution	3. On Price Paid	4. On The Amount Of Truck Movements	5. On The Amount Of Piggyback Movements
[illegible] EFFECT C ([illegible] -300 Cwt.)	-20725.00*	-19945.00	57469.00**	41450**	-43462**
[illegible] EFFECTS					
A	8691.20	9162.36	-23176.88	-21075	13388
B	-13870.22	11972.08	19867.13	- 9325	12363
D	46275.35***	44675.35***	45903.25	-72962***	70950***
E	7993.99	7842.75	19013.13	- 213	2550
F	- 9976.69	- 9012.90	63420.75**	36425**	-35588**

*Significant at the 10% level.

**Significant at the 5% level.

***Significant at the 1% level.

<u>Price Paid</u>--The main effects of a change in truck load factor was significant in both categories of movement. The effect in both cases was to increase the price of services of the transportation company compared .. the single modal carriers. Several interaction effects were significant as well. The interactions of truck load factor with (1) rail operating ratio (CB), (2) system capacity (CE), and (3) system logistics constraints (CF) were all significant in TL/CL movements. The last two interaction effects acted to increase the price paid while the first acted to decrease the price paid.

<u>Amount of Truck Movements</u>--The change in truck load factor had no significant effect on the amount of product moved by truck in the TL/CL movement classification. This test factor change did, however, cause a significant increase in the amount of truck movements of the transportation company vis-á-vis the single modal carriers for the LTL movements. There were also two significant interaction effects in the LTL classification. The interaction with rail load factor served to decrease the number of truck movements significantly. On the other hand, the interaction of truck load factor with shippers' logistics constraints served to increase the amount of Cwt. moved by truck.

<u>Amount of Piggyback Movements</u>--The amount of Cwt. moved by piggyback was significantly increased in TL/CL movements and was significantly decreased in LTL movements by an increase in truck

load factor. There were three significant interaction effects. For TL/CL movements the interaction with a low system capacity (CE) significantly decreased the number of piggyback movements. For LTL movements, the interaction of high truck load factor with high rail load factor served to increase the amount of Cwt. moved by piggyback. On the other hand, the interaction with low shippers' logistics constraints acted to reduce the number of piggyback movements.

Explanations--Because of the large number of significant interactions associated with a change in the truck load factor, discussion of the effect of a change in this test factor will be centered on the main effects. Interaction effects will be examined for trends rather than discussing each significant interaction effect individually.

In the LTL movements, the increase in truck load factor caused the expected contribution of the transportation company compared with its single modal counterparts to decrease. This is due to the fact that with a high truck load factor less traffic was allocated to piggyback movements by the transportation company. This is because an increase in the load factor of the trucker reduces the cost per Cwt. of moving goods. Since cost is directly related to the rate (the full cost), the trucker became more competitive with piggyback movements. Hence the transportation company had little opportunity to shift traffic from truck to piggyback movements with its attendant greater profit contribution. The effect of the change in truck load factor did decrease the difference between the two systems actual contributions but was not quite statistically significant at the 10% level.

That the above reasoning is correct is borne out by the fact that the transportation company moved significantly many more Cwt. by truck than when the truck load factor was at its low level in the LTL category. Correspondingly, the transportation company moved much less traffic by piggyback than when the truck load factor was at its low level.

A peculiarity in the main effects brought about by the change in the truck load factor is that the price paid for LTL transportation by transportation company users is significantly higher than when the truck load factor was at its low level. This is an interpretation problem which again deals with the nature of the performance measures being a difference between the two approaches to transportation. The increase in truck load factor did significantly raise the price paid from the average found in Table X. Even with this rise in price paid between the two forms, the transportation company would still have negative effect on the total price paid by users. That is, if the deviation from the average caused by an increase in truck load factor was added to the average difference, the figure would still be negative by a large amount thus indicating the transportation company still creates economies for shippers.

Before considering the TL/CL movements, the effect of changing the truck load factor on the LTL interaction effects will be examined. Four of the six significant interaction effects were the interaction with a change in rail load factor (CD). The other two significant interactions dealt with the interaction with a change in shippers' logistics constraints (CF).

The CD interactions had the effect of significantly raising expected and actual contributions and raising the amount of Cwt. moved by rail while reducing the amount of truck movements. This is as one would expect. The combination of high truck and rail load factors made piggyback movements the least cost (rate) maximum contribution method of movement. The piggyback movements had a larger contribution associated with them than did the truck movements. Hence the transportation company substituted piggyback movements for truck movements subject to logistics and capacity constraints. This had the effect of increasing expected and actual contributions over the single modal trucker.

The significant CF interactions had the effect of raising the price paid by users over the average and reducing the number of piggyback movements below the average difference as expressed in Table X. Again this is so because, in general, an increase in the load factor of the trucking mode made this method of movement dominant. Most moves took place under these circumstances by truck, which in general had a larger price tag than when coordinated transportation was used under different factor combinations.

The change in truck load factor significantly increased the TL/CL price paid and the amount of Cwt. moved by piggyback. The increase in truck load factor made piggyback movements an attractive intermediate length of haul method of movement. In the single modal situation, however, the trucker tended to make truck movements as much as possible because of the necessity of splitting the contribution in Plan I moves. The transportation company utilized piggyback movements to a greater extent when the total contribution was greater.

The effect of this factor on the price paid by users is more complicated to analyze. Certainly, the interaction with low system capacity (CE) is understandable. The price paid significantly increased when the trucking capacity was exceeded. This is because alternative more expensive methods of movement must take place to satisfy demand. As far as the main effect is concerned, the analysis of the printouts of the simulation indicated that the increase in truck load factor made trucking moves more attractive to the trucker as well as the transportation company. The simulation printouts revealed that in a large number of cases, due to chance, the single modal carrier would run out of capacity before demand was satisfied. The transportation company while still operating under low system capacity had an additional amount of trucking capacity at its disposal. This extra capacity was what the railroad had available for Plan II moves. Thus the transportation company was able to satisfy all of the demand and as a result the price paid for services correspondingly rose.

<u>Effect of a Change in Rail Load Factor (400 Cwt.-800 Cwt.) on the Performance Measures</u>

The effects of the change in rail load factor from 400 Cwt. to 800 Cwt. are presented in Table XVa and XVb. The change in this test factor produced many significant results.

<u>Expected Contribution</u>--The increase in rail load factor had the effect of significantly reducing the expected profit contribution for both TL/CL and LTL movements. The change in this factor also produced three significant interaction effects in the expected contribution performance measure. In TL/CL movements the interaction of increased rail load factor with (1) a reduction in rail operating ratio (DB) and (2) a reduction in the size of shippers' logistics constraints both served to significantly reduce the expected contribution of the transportation company as compared to the single modal companies. In the LTL category of movements, the interaction effect of a change in rail load factor with a change in truck load factor (DC) significantly increased the expected contribution measure.

<u>Actual Contribution</u>--The main effects of increasing the rail load factor in both movement categories was to significantly decrease the actual contribution of the transportation company as opposed to the single modal carriers. The same interaction effects that were significant in the expected contribution measure are significant for the actual contribution measure also. These interaction

TABLE XVa: EFFECTS OF A CHANGE IN RAIL LOAD FACTOR ON THE TL, CL PERFORMANCE MEASURES.

EFFECTS:	1. On Expected Contribution	2. On Actual Contribution	3. On Price Paid	4. On The Amount Of Truck Movements	5. On The Amount Of Piggyback Movements	6. On The Amount Of Rail Movements
MAIN EFFECT D (400 Cwt.-800 Cwt.)	-19133.32**	-17950.55**	3011.50	11963	-32363*	37650**
INTERACTION EFFECTS						
A	- 948.85	- 116.12	-11934.25	- 8888	- 5663	1650
B	-16116.80**	-17391.69**	6890.00	8738	27487	-30825**
C	1493.65	1734.12	2476.25	- 7763	- 3263	15150
E	3163.99	2866.44	- 5595.25	- 8288	21713	-15600
F	-15597.23**	-15834.73**	- 1122.00	15938	-33938**	17850

*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

TABLE XVb: EFFECTS OF A CHANGE IN RAIL LOAD FACTOR ON THE LTL PERFORMANCE MEASURES

EFFECTS:	1. On Expected Contribution	2. On Actual Contribution	3. On Price Paid	4. On The Amount Of Truck Movements	5. On The Amount Of Piggyback Movements
MAIN EFFECT D (400 Cwt.-800 Cwt.)	-30683.75**	-29593.60**	-163386.13***	-88888***	68200***
INTERACTION EFFECTS					
A	1938.40	2465.07	22503.75	- 3088	7625
B	- 8329.47	- 8319.84	-24855.25	-21338	12150
C	46275.35***	44675.85***	45903.25	-72962***	70950***
E	1887.34	1852.36	-15692.00	6150	-22488
F	-18317.27	-18066.16	-88548.13**	-35938*	18100

*Significant at the 10% level
**Significant at the 5% level
***Significant at the 1% level

effects--DC for LTL movements and DB and DF for TL/CL movements--produced the same kind of reaction of the system in this measurement as they did for expected contribution.

Price Paid--The change in rail load factor had no significant effect on the price paid for transportation in TL/CL movement category. The change in this test factor did, however, significantly reduce the price transportation company customers paid for transportation services as compared to the single modal counterparts in the LTL category of movement. The interaction with shippers' logistics constraints (DF) also significantly reduced the price paid for services in the LTL category.

Amount of Truck Movements--The increase in rail load factor significantly reduced the number of Cwt. moved by truck in the transportation company situation vis-á-vis the single modal carrier in the LTL category of movements. Also in LTL movements, the interactions with increased truck load factor (DC) and with reduced shippers' logistics constraints (DF) significantly reduced the amount of truck movements.

Amount of Piggyback Movements--The change in rail load factor significantly increased the number of Cwt. moved by piggyback for LTL movements. This factor change had the exact opposite effect on the amount of piggyback movements in the TL/CL movement category. There were two significant interaction effects also. In the TL/CL category, the interaction with a reduced level of shippers' logistics constraints (DF) also served to significantly reduce the amount of Cwt. moved by piggyback methods. In the LTL category, the interaction with increased truck load factor (DC) served to significantly increased the number of Cwt. moved by piggyback.

Amount of Rail Movements--The change in rail load factor led to a significant increase in the amount of rail boxcar movements by the transportation company over what the single modal companies moved by rail, as one might expect. The interaction with a low rail operating ratio (DB) served to significantly reduce the number of rail movements of the transportation company as compared to the single modal companies.

Explanations--The explanation of how a change in rail load factor produced significant effects on the TL/CL performance measures will be presented first, after which attention will be given to the LTL performance measures. The increase in rail load factor significantly reduced the expected and actual contributions of the transportation company as compared to its single modal counterparts. This is due to the fact that the change in this factor made the single modal railroad, in most cases, the dominant carrier. In other words this test factor change, caused for the most part, most of the single modal traffic to move by rail except where constrained. Thus the formation of a transportation company had little effect on the manner in which movements took place under these circumstances, and hence did not increase profit contribution as in other situations.

In most situations the single modal trucker would attempt to compete with the single modal rail carrier in short hauls by using Plan I moves. Thus the amount of Cwt. moved by the transportation company by piggyback was significantly reduced as compared to the amount the single modal carriers moved by this method. This is because, under most circumstances, the rail mode was low cost but piggyback Plan I was within the price range of competition. Thus the transportation company shifted movements which the single modal carriers moved by piggyback to rail. This correspondingly explains why the change in rail load factor led to a significant increase in the amount of boxcar movements.

The significant interaction effects with rail operating ratio (DB) were explained for the various performance measures earlier in this chapter, when the change in rail operating ratio was examined for effects. The interaction with a low level of shippers' logistics constraints (DF) significantly reduced the expected and actual contribution of the transportation company as well as the number of Cwt. moved by piggyback. The lower level of shippers' logistics constraints allows the carriers more freedom in selecting the methods of movement to satisfy shippers' demand than does a high level of logistics constraints. As such, the interaction of high rail load factor with a low level of logistics constraints produced the same kind of effect as the main effects of changing rail load factor, only to a larger degree.

Attention will now be turned to examine how a change in rail load factor affected the LTL performance measures. The effects of increasing the rail load factor was to significantly reduce the expected and actual contribution as well as the price paid by shippers and the amount of Cwt. moved by truck, of the transportation company vis-á-vis the single modal companies. The reason for the significant decline in expected and actual contribution and price paid is that the high rail load factor has the effect of lowering the out-of-pocket costs per Cwt. which is directly related to the rate charge shippers (the fully distributed cost), hence the price paid by shippers is less than in the single modal situation. The full costs of the LTL piggyback movements were substantially less in most cases than the fully distributed truck costs. In the single modal situation, the trucker would set his rate at his fully distributed cost since he does not have to participate in Plan I moves. This had the effect of raising the profit contribution of trucker relative to the transportation company because the transportation company priced its services at the full cost of the low cost mode. Even with this difference in pricing between the systems, the transportation company out-earned the single modal companies. The effect of increasing the rail load factor was to decrease the amount of expected and actual profit contribution differential between the systems. Even so, if one looks at Table X, one can see that even after subtracting the effects of this factor from the averages in the table the transportation company is still more "profitable" than the single modal companies.

It should be pointed out that the pricing actions of the trucker differ substantially between the two classes of movement--LTL and TL/CL. In both cases, the trucker does not have to participate in Plan I moves if he does not wish to. The same is true for the railroad. In the TL/CL market, the trucker has an incentive to participate in Plan I moves that he does not in the LTL market. In the TL/CL market, the railroad is competitive for traffic that the trucker wants to carry and vice versa. Thus if the trucker is not low cost he will want to participate in Plan I moves if this is the only manner in which he can obtain some contribution. This is not the case in the LTL market. The railroad does not actively compete for LTL movements in the portion of the market considered in this study.[9] Thus the trucker will price his LTL services at his full costs in all cases.

The result of increasing the rail load factor was to significantly increase the number of piggyback movements and correspondingly decrease the number of truck movements. This had the effect of significantly reducing the price paid by shippers which is due mainly to the lower priced rail related piggyback substitution for truck movements.

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[9] It must be remembered that this study is examining only common carrier rail and truck movements, and associated Plan I and Plan II piggyback movements in both traffic categories. To lend some credence to the above statement that railroads do not actively seek LTL movements in Plan II moves the author contacted the Burlington Northern Railroad to determine the type of traffic being carried in Plan II moves. Mr. Robert Prokopp in the TOFC Department indicated approximately 99% of Plan II moves are TL lots. To double check this figure, Mrs. Rosmary Hurd in the Freight Agent's Office was contacted; she placed the estimate of 95% of the Plan II movements were truckload movements.

The interaction effects with a change in truck load factor (DC) which had significant effects on the performance measures were discussed in the section explaining the effects of a change in truck load factor. There were two significant interaction effects of an increase in rail load factor with a reduced level of shippers' logistics constraints (DF). The DF interactions served to significantly reduce the price paid and the amount of truck movements. This is due to the fact that reduced levels of logistics constraints allow the transportation company to substitute piggyback service for truck service to a greater degree than a high level of logistics constraints.

Effects of a Change in the Capacity of the System on the Performance Measures

The effects which resulted from a change in the level of the capacity in the system are displayed in Table XVIa and XVIb. The change in the level of this factor also produced several significant results.

Expected Contribution--The reduction in the level of system capacity had no appreciable effect on the expected contribution of the transportation company as compared to the single modal companies in either the TL/CL or LTL category of movement. The interaction with the level of truck load factor (FC) significantly increased the expected contribution of the transportation company vis-à-vis the single modal carriers.

TABLE XVIa: EFFECTS OF A CHANGE IN THE CAPACITY OF THE SYSTEM ON THE TL, CL PERFORMANCE MEASURE

EFFECTS:	1. On Expected Contribution	2. On Actual Contribution	3. On Price Paid	4. On The Amount Of Truck Movements	5. On The Amount Of Piggyback Movements	6. On The Amount Of Rail Movements
MAIN EFFECT E (High-Low) System Capacity	- 9863.27	- 4505.48	17113.50**	8888	70013***	-70725***
INTERACTION EFFECTS						
A	8883.32	8339.89	1146.75	15488	-26588	26175*
B	- 5178.44	- 5203.52	- 5346.00	- 7988	26513	-19350
C	1'201.20*	13276.18*	17726.25**	17063	-30338*	13725
D	3163.99	2866.44	- 5595.25	- 8288	21713	-15600
F	- 2351.25	- 1870.43	11273.00	- 788	44288**	-36375**

*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

TABLE XVIb: EFFECTS OF A CHANGE IN THE CAPACITY OF THE SYSTEM ON THE LTL PERFORMANCE MEASURES

EFFECTS:	1. On Expected Contribution	2. On Actual Contribution	3. On Price Paid	4. On The Amount Of Truck Movements	5. On The Amount Of Piggyback Movements
MAIN EFFECT E (High-Low System Capacity)	-17163.23	-16276.19	-12721.50	30338*	-46675**
INTERACTION EFFECTS					
A	11475.65	11886.35	22028.38	9613	- 3725
B	- 8658.26	- 8484.82	-12578.88	17288	-22125
C	7993.99	7842.75	19013.13	- 213	2550
D	1887.34	1852.36	-15692.00	6150	-22488
F	-13412.49	-12602.80	-39882.25	38	-19225

*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

Actual Contribution--As in the case with expected contribution the change in the level of system capacity did not significantly effect this performance measure in either category of movement. The EC interaction significantly increased the TL/CL actual contribution, the same reaction it caused in the expected contribution measure.

Price Paid--The change in this test factor had no appreciable effect on the price paid for LTL movements. The reduction in the level of system capacity did significantly raise the price paid for transportation services for TL/CL movements. The interaction with a change in truck load factor (EC) acted to significantly increase the price paid by users in the TL/CL category of movement.

Amount of Truck Movements--The decrease in the level of system capacity significantly incr ed the number of LTL truck movements the transportation company ade compared to its average usage of truck movements. This test factor change had no effect on the amount of truck movements in the TL/CL market.

Amount of Piggyback Movements--The change in the level of capacity significantly increased the numb r of piggyback movements in the TL/CL market, while it acted to significantly decrease the amount of piggyback movements in the LTL market. The interaction with truck load factor (EC) acted to significantly decrease the amount of piggyback movements, while the interaction with a change in the level of logistics constraints (EF) acted to increase the amount of piggyback movements in the TL/CL market.

Amount of Rail Movements--The reduction in the level of system capacity served to significantly reduce the number of rail boxcar movements in the TL/CL market. The interaction with the reduction in truck operating ratio (EA) significantly increased the amount of rail movements. The interaction with a reduction in the level of shippers' logistics constraints served to significantly reduce the amount of rail movements the transportation company made with respect to the average difference between the two systems or modes of operation.

Explanations--The discussion of the causative effects of the reduction in system capacity will begin with the TL/CL market. The reduction in the amount of capacity significantly increased the price paid for TL/CL movements. The reason for this is that the restriction on capacity necessitated a greater dependence on full cost pricing on the part of the single modal carriers. That is, in situations where the capacity was not great enough to satisfy demand, as a result of poor market estimation and allocation, the single modal carriers could not nor did they wish to transfer unmet demand to the competitive mode. The transportation company, on the other hand, when it did exhaust the capacity of one mode would shift the unmet demand to another method of movement. The end result was that the transportation company did not have as much unsatisfied demand as the single modal carriers and that, as such, the price paid for transportation was greater than that paid to single modal carriers.

These findings are further supported by the fact that a change in capacity resulted in a significant reduction in rail movements and a significant increase in piggyback movements. This resulted from the fact that, in most situations, the rail mode was the scarce resource. The transportation company would then shift the unmet "boxcar demand" to piggyback moves.

The significant TL/CL interaction effects with the change in truck load factor (EC) on the various performance measures were explained in an earlier section of this chapter. The interaction with a low level of shippers' logistics constraints (EF) significantly increased the amount of piggyback movements and significantly decreased the amount of rail movements. This is the same reaction as the main effect, the change in system capacity created, except to a lesser degree. This is as one would expect. The change in the level of logistics constraints controls the amount of traffic which is subject to intermodal competition. Thus the result of expanding the competitive traffic market and reducing the amount of capacity was to cause the transportation company to shift competitive demand from the scarce resource to an available next most profitable method of movement.

There were no significant interaction effects associated with this test factor in the LTL category of movement. The reduction in system capacity significantly reduced the amount of piggyback movement and correspondingly significantly increased the amount of truck movements in the LTL market segment. This is because the maximum contribution method, in general, was piggyback movements in the LTL market. The scarce resource was also the amount of flatcar capacity (See Table I, Chapter III). Thus reducing the system capacity, in effect reduced the number of piggyback movements the transportation company could make. The unmet "piggyback demand" was shifted to the trucking mode.

Effects of a Change in the Level of Shippers' Logistics Constraints on the Performance Measures

The effects which resulted from lowering the level of shippers' logistics constraints are presented in Tables XVIIa and XVIIb. The change in this test factor produced several significant results.

Expected Contribution--In the TL/CL category of movements, the reduction of the amount of traffic subject to shippers' logistics constraints, significantly increased the expected contribution of the transportation company over its single modal counterparts. The interaction with a change in rail load factor (FE) served to significantly reduce the TL/CL expected profit measure.

TABLE XVIIa: EFFECTS OF A CHANGE IN THE LEVEL OF SHIPPERS' LOGISTICS CONSTRAINTS ON THE TL, CL PERFORMANCE MEASURES

EFFECTS:	1. On Expected Contribution	2. On Actual Contribution	3. On Price Paid	4. On The Amount Of Truck Movements	5. On The Amount Of Piggyback Movements	6. On The Amount Of Rail Movements
MAIN EFFECT F (High-Low Level of Logistics Constraints)	33498.21***	32467.55***	12481.75	-18938	-73237***	93825***
INTERACTION EFFECTS						
A	- 1067.69	- 2162.66	3360.50	8813	- 1983	- 2025
B	11358.43	11187.30	- 3568.75	- 8362	- 9938	17700
C	874.39	114.37	13872.50*	- 8063	24563	- 5175
D	-15597.23**	-15834.73**	- 1122.00	15938	-33938**	17850
E	- 2351.25	- 1870.43	11273.00	- 788	44288**	-36375**

*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

TABLE XVIIa: EFFECTS OF A CHANGE IN THE LEVEL OF SHIPPERS' LOGISTICS CONSTRAINTS ON THE LTL PERFORMANCE MEASURES

EFFECTS:	1. On Expected Contribution	2. On Actual Contribution	3. On Price Paid	4. On The Amount Of Truck Movements	5. On The Amount Of Piggyback Movements
MAIN EFFECT F (High-Low Level of Logistics Constraints)	13197.35	13166.57	- 99579.38***	-89225***	71387***
INTERACTION EFFECTS					
A	-10859.11	-10837.74	19742.50	23500	-16113
B	11355.22	12028.06	-27597.25	- 1275	- 5063
C	- 9076.69	- 9012.90	63420.75**	36425**	-35588**
D	-18317.25	-18066.16	-88548.13**	-35938*	18100
E	-13412.49	-12602.80	-39882.25	38	-19225

*Significant at the 10% level.
**Significant at the 5% level.
***Significant at the 1% level.

<u>Actual Contribution</u>--The change in the level of logistics constraints had the same effects on this performance measure as it did on expected contribution.

<u>Price Paid</u>--The change in this test factor significantly reduced the price paid for LTL transportation services. In the LTL category the interactions with truck load factor (FC) and rail load factor (FD) served to significantly increase and decrease the price paid for LTL movements, respectively. In the TL/CL category of movement, the interaction with truck load factor (FC) also served to significantly increase the price paid for transportation.

<u>Amount of Truck Movements</u>--The change in the level of shippers' logistics constraints had no appreciable effect on the amount of Cwt. moved by truck for TL/CL movements. In the LTL category of movements, the reduction in the level of logistics constraints significantly reduced the amount of Cwt. the transportation company moved by truck in relation to the single modal carriers. Also for LTL movements, the interactions with truck load factor (FC) and rail load factor (FD) significantly increased and decreased the number of Cwt. moved by truck, respectively.

<u>Amount of Piggyback Movements</u>--The reduced level of logistics constraints served to significantly increase the amount of LTL Cwt. moved by piggyback. The change in this test factor had just the opposite effect on the amount of TL/CL Cwt. moved by piggyback;

that is, it significantly reduced the piggyback movements of the transportation company compared to the single modal carriers. In the LTL market, the interaction with a change in truck load factor (FC) significantly decreased the number of piggyback movements. There were two significant interaction effects in the TL/CL market. The interaction effect with rail load factor (FD) acted to significantly decrease the number of piggyback movements. The interaction effect of a reduction in logistics constraints with a reduction in system capacity (FE) significantly increased the amount of Cwt. moved by piggyback.

<u>Amount of Rail Movements</u>--The reduction in the level of logistics constraints served to significantly increase the amount of Cwt. moved by rail boxcar in the TL/CL category of movement. The interaction with a low level of system capacity (FE) acted to significantly decrease the number of boxcar movements.

<u>Explanations</u>--All of the significant interaction effects caused by a change in the level logistics constraints have been discussed in previous sections of this chapter. Therefore, attention will now be placed on the explanations as to how the change in this test fact r caused significant main effects in the various performance measures. The significant main effects for TL/CL movements will be discussed first.

Wi· the lower level of logistics constraints imposed on the simul .n, the single modal trucker, when he was not the low cost carrier, would try to compete for traffic whenever possible by utilizing Plan I movements or by pricing trucking movements at the low cost method of movement. When the logistics constraints were low, this meant considerably more traffic was moved by piggyback in the single modal system than when the constraints were set at a high level (See Table I, Chapter III). The transportation company, when faced with low logistics constraints, used the method of movement to satisfy unconstrained demand that had the maximum contribution. In a large number of situations that maximum contribution method of movement turned out to be the rail mode. For TL/CL movements then, the change in logistics constraints caused the transportation company to use significantly more rail movements and less piggyback movements than the single modal carriers. This resulted in greater expected and actual contributions for the transportation company than its single modal counterparts because, in general, the single modal equipment allocation decisions did not result in the maximum system wide contribution which the transportation company did obtain.

In the LTL market segment, the reduced level of logistics constraints found the transportation company shifting a significant amount of unconstrained traffic, that the single modal carriers were moving by truck, to piggyback movements. The transportation company did this when the contribution of piggyback moves was greater than that of truck moves. Although the operations of the transportation company did not result in a significant increase in contribution as a result of a change in the level of logistics constraints, it did decrease the price paid by users for transportation services. The reason for this is that, in most situations, when the transportation company utilized piggyback movements this method was the low cost (rate) method. Thus piggyback movements significantly reduced the cost of transportation service for the customers of the transportation company as compared to the cost paid by users in the single modal system.

Summary

Because of the length of this Chapter, a brief summary of the important results is appropriate. To begin with it was found that most of the average differences of the performance measures between the transportation company and the single modal carriers were significant. More specifically, for TL/CL movements it was found that the expected and actual contribution of the transportation company were significantly greater than the sum of these measures for the single modal carriers. Furthermore, the transportation company made significantly less piggyback movements than the single modal carriers. In the LTL category of movements, the expected and actual contribution of the transportation company was again significantly larger than the combined contributions of the single modal carriers. The transportation company also had the effect of significantly reducing the price paid by shippers for LTL transportation services. The transportation company made significantly fewer truck movements and significantly more piggyback movements than did the single modal carriers.

The prime consideration of this chapter was the identification and explanation of the manner in which the levels of the test factors effect the average performance measures. The chapter presented the analysis of the effects produced by the six test factors, for each level of the size of shipments parameter, on each of the performance measures. The results of the simulation are graphically displayed in Tables XIIa through XVIIb. The test factors produced several significant main and interaction effects in the performance measures.

The following tables recapitulate the significant main and first-order interaction effects. In the tables an arrow pointed upward (↑) indicates the effect increased the difference between the performance measures of the transportation company as compared to the single modal carriers. An arrow pointed downward (↓) indicates the effect decreased the difference between the performance measures. The absence of an arrow indicates the factor or factor combination had no effect on the performance measures.

TABLE XVIII

(a) SUMMARY OF MAIN EFFECTS ON THE TL/CL PERFORMANCE MEASURES

Main Effect	Expected Contribution	Actual Contribution	Price Paid	Truck Movements	Piggyback Movements	Rail Movements
A						
B	↑	↑	↓		↓	↑
C			↑		↑	
D	↓	↓			↓	↑
E			↑		↑	↓
F	↑	↑			↓	↑

(b) SUMMARY OF MAIN EFFECTS OF THE LTL PERFORMANCE MEASURES

Main Effect	Expected Contribution	Actual Contribution	Price Paid	Truck Movements	Piggyback Movements
A					
B	↑	↑			
C	↓		↑	↑	↓
D	↓	↓	↓	↓	↑
E				↑	↓
F			↓	↓	↑

TABLE XIX

(a) SUMMARY OF INTERACTION EFFECTS ON THE TL/CL PERFORMANCE MEASURES

Interaction Effect	Expected Contribution	Actual Contribution	Price Paid	Truck Movements	Piggyback Movements	Rail Movements
AE						+
BC			+			
BD	+	+				+
CE	+	+	+		+	
DF	+	+			+	
EF					+	+

(b) SUMMARY OF INTERACTION EFFECTS ON THE LTL PERFORMANCE MEASURES

Interaction Effect	Expected Contribution	Actual Contribution	Price Paid	Truck Movements	Piggyback Movements
CD	+	+		+	+
CF			+	+	+
DF			+	+	

Economies of Scale

One facet of the possible economic advantages a transportation company might enjoy over its single modal counterparts that was not directly considered in the preceding analysis is the possibility of achieving economies of scale as a result of combining two different modes of transportation. As indicated in Chapter I, there is wide disagreement on the part of transportation economists as to whether or not a multi-modal transportation company could achieve significant economies of scale. The disagreement centers on the question of how similar are the operating functions of the combining modes and is there enough similarity to allow the transportation company to centralize functions and eliminate duplicative functions, and so forth. These kinds of questions will be addressed in Chapter VI. As will be pointed out in Chapter VI, there really has not been enough research done in this area of the transportation company concept to answer the question of whether or not there are substantial economies of scale to be obtained from combining separate modes.

How does the fact that economies of scale were not directly considered in the analysis affect the results of the study? To understand what effect this has on the results of the study, one must know exactly how the simulation considered economies of scale. The cost data, for a given set of parameters, which the transportation company utilized to make pricing and equipment allocation decisions was exactly the same as the cost data, the single modal carriers utilized to make their decisions. As such the fixed and/or common costs, which are the costs which economies of scale would effect, for each method of movement were the same across the two methods of operation, i.e., transportation company vis-à-vis single modal carriers. In essence, this means that the transportation company considered in this study was operating with no realized economies of scale resulting from the combination of two separate modes of transportation. This conservative approach to the economies of scale question means that the significant effects described earlier in this chapter would still be valid even if there were some economies of scale involved in forming transportation companies.

The reason why the results of this study would remain valid even if there were substantial economies of scale involved in operating transportation companies is because the nature of the performance measures which deal directly with costs and rates are based upon the total contribution to fixed and/or common costs and profit margin. Thus, while economies of scale may significantly effect the profitability of a transportation company, they have no effect whatsoever on the contribution which was used as a measure of economic impact in this study. One may, however, think of the total contribution as a measure of profitability. This is because the same fixed and/or common costs would be subtracted from the total contribution. Thus if it were finally determined that there were no economies of scale to be obtained from the formation of transportation companies, the results of this study would be directly applicable. If there are some economies of scale, the significant results would remain significant. If the economies were substantial enough, they may have the effect of adding a number of additional effects to the significant list. This is because the economies of scale would reduce the fixed and/or common costs as compared to the sum of the fixed costs of the single modal carriers. Thus increasing the profitability gap between the two organizational approaches.

As stated previously, further research must be directed at determining the extent that functions may be combined or partially eliminated in multi-modal transportation companies before reasonable estimates of economies of scale may be made. Thus the performance measures used in this study avoid this uneasy task and yet provide valuable information as to the economic impact a transportation company would have.

The Significance of Interaction Effects

Because there was a number of significant interaction effects, 47 of 330, a discussion on how these interactions have been interpreted is warranted. It will be recalled that in the use of the fractional factoral design, the main effects and first order interaction effects are confounded with higher order interaction effects. It has been assumed, as stated Chapter IV, throughout that the high order interaction effects are zero. That is, in the explanations of how a change in the factor levels "caused" the significant effects it has been assumed that the aliases of the main and first order interaction effects are zero. This author believes this assumption to be reasonable. The reader is left to his own conclusion about the validity of this assumption. At any rate, if the reader is not inclined to adopt the assumption the investigation has at least identified the groupings of possible interactions which have caused the significant behavior.

Another matter concerning the rejection of the null hypothesis, that an interaction effect is zero, deserves some attention. If an interaction effect has been determined to be significant, is the rejection of the null hypothesis concerning the main effect of a component of that interaction effect meaningful? That is once an interaction effect has been found to be significant can the main effect be considered and if so is it meaningful? Guenther states that if the interaction is found to be significant, the main effect can still be tested but the results of such tests are usually of no interest. Guenther goes on to say, "when interactions are present, the best treatment combinations, rather than the best levels of treatments, are usually the prime concern".[7] This may be true in most experimental settings, but this is not the case in this particular project. The reason for this is that the object of this dissertation is to obtain a broad picture of the effects specific factors have on the operating characteristics of a transportation

[7]Guenther, op.cit., p. 103.

company. The intent is to show over the spectrum of possible test factor levels the effect these factors have in general on the operations of a transportation company as compared to the operations of single modal companies. This kind of broad or general information would be useful in focusing attention upon a possible change in public policy as it pertains to multi-modal transportation companies. That is, policy makers would be interested in the main effects of this study in so far as if there were a change in policy it would likely be general. That is, the Congress or the I.C.C. would be interested in figures as to how the transportation company concept fairs over the average level of the factors. These are the main effects. The carriers on the other hand would be interested in how the specific levels of the factors affect the performance measures. In other words the carriers would want to know how they would benefit from the creation of a transportation company with the specific levels of the factors the interested carrier have. This study provides both of these informational requirements. Thus both the significant interaction and main effects of this study are of interest.

CHAPTER VI

OTHER ASPECTS OF COMMON OWNERSHIP

In the last chapter it was found that the formation of transportation companies can result in economic benefits for both the providers and users of transportation services. Before one can really interpret the meaning of these results and outline the implications they have for the transportation industry, the significance of the economics of common ownership must be related to the other aspects of the issue. As mentioned in Chapter I, the question of whether or not transportation companies should be established in a multidimensional issue. That is, the formation of transportation companies involves economic, legal, and social issues which must be resolved before such companies can be established.

The purpose of this chapter is to identify the other aspects of the transportation company concept and discuss their relationship to the research accomplished in this study. This chapter consists of two parts. The first identifies the obstacles which currently bar the establishment of transportation companies in the United States. The second section of the chapter relates these obstacles to the research conducted in this study. The implications and interpretation of the results of this dissertation in the light of the total aspects of the concept will be reserved for the final chapter.

Obstacles to Integration

Sampson and Farris have noted three types of obstacles which stand in the way of integration in domestic transportation. These are regulatory obstacles, inherent obstacles in integration, and environmental obstacles.[1]

Regulatory Obstacles

In this section the National Transportation Policy, the laws applicable to common ownership, the case by case development of the I.C.C. criteria for determining when a railroad may own a trucking company, and the role of the Department of Transportation will be analyzed.

The National Transportation Policy (NTP)--The National Transportation Policy, as stated in the Interstate Commerce Act is as follows:

> It is hereby declared to be the national transportation policy of the Congress to provide for fair and impartial regulation of all modes of transportation subject to this Act, so administered as to recognize and preserve the inherent advantages of each; to promote safe, adequate, economical, and efficient service and foster sound economic conditions in transportation and among the several carriers; to encourage the establishment and maintenance of reasonable charges for transportation services, without unjust discriminations, undue preferences or advantages, or unfair or destructive competitive practices; to cooperate with the several states and the duly authorized officials thereof; and to encourage fair wages and equitable working conditions; all to the end of developing, coordinating, and preserving a national transportation system by water,

[1]Sampson and Farris, op.cit., p. 332.

> highway, and rail, as well as other means, adequate to meet the needs of the commerce of the United States, of the Postal Service, and of the national defense. All of the provisions of this Act shall be administered and enforced with a view to carrying out the above declaration of policy.[2]

After a careful reading of the NTP, one can conclude that there is nothing explicitly stated which forbids the creation of a transportation company if the creation of such a company could be proven to be "beneficial." However, in the phrase _fosters sound economic conditions in transportation and among the several_ carriers, the term _several carriers_ has not been interpreted by the I.C.C. as a reference to the carrier industries or modes, but rather to the protection of the business stability of individual carriers (firms) of a mode.[3] Also, _to preserve the inherent advantages of each_ mode implies a sacredness of division or separation of each mode from one another. Although the term inherent advantages has never been adequately defined, it is usually taken to mean that each mode has some unique characteristics that enable it to offer services for transportation users which other modes cannot.[4] This statement should not, however, prevent two or more modes from combining services to create

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[2] _The Interstate Commerce Act_, (Washington, D. C.: Government Printing Office, 1968), p. 1.

[3] _National Transportation Policy_, _op.cit._, p. 37.

[4] Locklin states that the low cost carrier, on a fully distributed cost basis, has the "inherent avantage". (D. Philip Locklin, _Economics of Transportation_, sixth edition, (Homewood, Ill.: Richard D. Irwin, Inc., 1966), p. 865.

some new inherent advantage, but the implicit language of the NTP does not seem amenable to such a consideration. To sum up, as one scholarly and oft quoted source puts it, "this statement of policy, at least as it has been interpreted, has not gone beyond the frame of reference of promoting the stability of each mode as a basic requirement for a healthy and satisfactory national transportation policy".[5]

Applicable Laws--There are four mutually exclusive ways in which a railroad and a trucking company may form a transportation company. First, the trucker may acquire an existing railroad or secondly, he may seek new rail operating rights and, if granted, build a new railroad. Since trucking companies, even the largest ones, are much smaller asset-wise than railroads, it is unlikely that either of these possibilities would occur. The second method would be even less likely since the rail mode already connects all manufacturing sites of any size. More likely methods of forming the transport company would be thirdly, for the railroad company to acquire an existing trucking firm or fourthly, the railroad company could apply for new trucking operating rights and if granted, purchase the relatively inexpensive motor equipment.

If either carrier attempts to merge with the other, they must receive specific approval from the I.C.C. as outlined in

[5] *National Transportation Policy*, *op.cit.*, p. 37.

in Section 5 of the Interstate Commerce Act (I.C.A.). If the railroad requests new motor carrier operating rights, it must obtain a certificate of public convenience and necessity as described in Section 206 of the Act. If the trucker wishes to construct new rail lines it must be granted permission by the I.C.C. under Section 1 (18) of the Act.

Since a trucking firm has never attempted to gain control of a railroad, there are no precedents which have been set by the I.C.C. and it is therefore uncertain as to the posture that the Commission would take regarding such a matter. If the Commission had developed a generally appropriate decision criterion for determining when transportation companies were desirable or "in the public interest", it would not matter which mode requested the merger or new operating rights as long as the proposal met the criterion.

There has been over the years, on the other hand, numerous attempts by the railroads to acquire control of motor carriers. As a result, the I.C.C. had developed a very explicit standard (perhaps unacceptable) for determining when a railroad may acquire a trucking firm by means of the two methods for doing such as mentioned above. Section 5 (2) (b) of the I.C.A. contains a special proviso relating to rail acquisition of motor carriers. This proviso stipulates that the Commission must find, if the applicant is a railroad, or owned by a railroad, "that the transaction proposed will be consistent with the public interest and will enable such carrier to use service by motor vehicle to public advantage in its operations and will not unduly restrain competition".[6]

To ensure that the above proviso is met, the Commission has evolved certain standards based on case precedents to apply to such proposals. Much of the following summary of the specific precedents was obtained from a study by Byron Nupp.[7] The first case was the Barker Case (Pennsylvania Truck Lines, Incorporated, Acquisition of Control of Barker Motor Freight, Inc., 1 M.C.C. 101 (1936) also 5 M.C.C. 9 (1937) and 5 M.C.C. 49 (1937)) in which the Commission decided to restrict or confine rail operated motor service to that which is "auxiliary and supplementary" to that performed by railroads disallowing truck service which would be strictly competitive with the rail operations. The Kansas City Southern Case (Kansas City Southern Transport Co., Inc. Common Carrier Application, 10 M.C.C. 221 (1938)) extended the Barker Doctrine to original certificates of public convenience and necessity not covered in Section 5. This case further restricted rail owned truck service to points on the rail line, and to shipments received or delivered by rail, and disallowed truck service between "key points" on the rail line. Since the Kansas City Southern and Barker Cases, several Supreme Court

[6] The Interstate [illegible] Act, op. cit., p. 29.

[7] Byron Nupp, "[illegible]" [illegible] 1960), [illegible]

cases (U.S. et.al., v. Rock Island Motor Transit Co. et.al., 340 U.S. 419 (1951); United States v. the Texas and Pacific Motor Transit Company, 340 U.S. 450 (1951)) have upheld the Kansas City Southern Doctrine.

The Commission applies the above standards in merger cases and in cases where new operating authority is sought. A very important point can be drawn from the above analysis. As Nupp puts it, intermodal combinations have been treated more restrictively than intramodal combinations because in addition to the usual "public interest" test, additional criteria have been established.[8] These restrictions were spelled out at a time when railroads held considerable monopoly power and later when the trucking industry was a struggling fledgling. This is clearly not the situation now. The recent deteriorating economic situation of a number of America's largest railroads can bear testimony to this fact.

The I.C.C. has then strictly interpreted the law as stated in Section 5 of the I.C.A. and "the intent appears to be more nearly to insure that each mode remains in competition with the others and to preserve all modes, rather than to provide the means for adapting them to places in accord with their relative economic capabilities".[9] Another source concludes,

> ...that the framework of the present regulatory policy...by failing to resolve the question of single ownership of several modes...has produced

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[8] Ibid., p. [illegible]

[9] [illegible]

> a general program of preserving the status quo which is in direct opposition to the overall objective of a dynamic transportation system which can best serve the economy and defense of the country.[10]

The Role of the Department of Transportation--One of the functions of the Department of Transportation as stated in the Declaration of Purpose of the Department of Transportation Act is to provide general leadership in the identification and solution of transportation problems. As such, research into the concept of the transportation company falls under the jurisdiction of this Department. A search of government documents or literature reveals that as of yet the Department has not published any material related to research on the transportation company concept. To determine if any work was currently being done on the subject the author wrote a letter to the Secretary of Transportation requesting information on research which the Department had done or is currently doing or is planning to do on the subject. The reply was negative.

Inherent Obstacles

As alluded to in the previous section of this chapter the formation of transportation companies would require voluntary action on the part of the participants. As Sampson and Farris put it:

[10] National Transportation Policy, op.cit., p. 38.

> Agreement among the firms being merged or being integrated is not always easy. Since many are corporations, many investors with diverse goals and objectives must be satisfied. This involves both debt and equity owners. Management itself may disagree. It is not easy to merge oneself out of a job, and a merged firm can have but one president and set of administrative officers. As we have seen, adjustments in the immediate period are almost inevitable when unification or integration takes place. ...The tendency to avoid adjustment and change is great in all businesses, and in some of the older transportation firms this inertia itself is a major obstacle. Therefore, there are obstacles in the very idea...of integration.[11]

This conclusion is supported by Germane, Glaskowsky and Heskett when they found:

> There is a strong tendency for railroad executives to think entirely in terms of railroading, for trucking company executives to think only in terms of trucking, etc. For example, it was no easy thing for some railroad executives to learn to think in terms of operating a coordinated service in partnership with truckers, a group long described by some railroaders as "hereditary enemies", "agents of the devil", or even stronger terms of opprobrium. On the other side, various trucking executives have been deeply suspicious of railroaders and their motives in offering piggyback service. These unfavorable railroader and trucker attitudes have served to slow the development of coordinated service.
>
> Even when there is ... no inherent animosity between the management groups concerned, ... there still remains the problems of communications.[12]

While Germane, Glaskowsky, and Heskett were talking specifically about coordinated services, their discussion seems equally applicable to the common ownership problem.

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[11] Sampson and Farris, *op.cit.*, p. 333.

[12] Germane, Glaskowsky, and Heskett, *op.cit.*, p. 71.

Environmental Obstacles

The very nature of our political and economic system may pose another obstacle to the formation of transportation companies. Again Sampson and Farris have succinctly stated this proposition as follows:

> ...The economic environment of the nation is quite oriented toward individual firms and competition. Unification and integration involve group action on the part of firms and often a decrease in competition. This may present an obstacle.
>
> From another point of view, the political climate may be a very real environmental obstacle. Transportation systems serve many towns, counties, and states. Each is a political unit with its representatives elected to promote the welfare of each particular governmental unit. ...Some politicians may...oppose [integration] not because it is economically unsound, but because it is politically expedient to do so. The political climate, then, may impose a very real obstacle to...integration.[13]

Relationship of this Study to the Obstacles

From the above discussion it is apparent that there are formidable obstacles which present barriers to the establishment of transportation companies. This thesis has demonstrated for the first time that there are definite economic advantages resulting from the formation of transportation companies for both the carriers and the users. Is this knowledge sufficient to remove the above mentioned obstacles to common ownership?

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[13] Sampson and Farris, op.cit., p. 333.

Before this question can be addressed, the author must acknowledge however that the research was undertaken in abstract, that is, apart from the real world. Thus before the conclusions of the study can be translated to the real world, the critical assumptions of the study must be analyzed for their impact. As will be seen shortly the validity of the assumptions cannot really be determined without further research in the appropriate areas.

The following discussion relates the results of this research to the obstacles which bar the formation of transportation companies. Attention will be focused on: (1) the need for further research on the common ownership question and how this needed research is related to the critical assumptions made in this study; and (2) the impact the knowledge obtained in this study may be expected to have on each of the obstacles to integration. The discussion will begin with inherent obstacles after which regulatory and environmental obstacles will be addressed.

<u>Relationship to Inherent Obstacles</u>

The focus of this dissertation has been on the determination of the economic feasibility of establishing intermodal transportation companies. The hypothetical firms modeled in Chapter II are assumed to be capable of effectively organizing to obtain their goals of maximizing their (profit) contributions. This brings up a series of questions which are concerned with what may be called the <u>managerial feasibility</u> of establishing transportation companies. The managerial feasibility of transportation companies raises questions of not only is it possible to organize and operate a multi-modal transportation company, but what is the best method of organizing a transportation company under a given set of circumstances. In the following paragraphs the author has posed a set of questions in the areas or organization, operations, marketing, and finance that should be answered before attempts are made to establish multi-modal transportation companies. It should be pointed out that the author does not suggest the lists of questions are complete but should give the reader an appreciation of the amount of research remaining to be accomplished.

Organizational Alternatives--The questions that must be answered in this area are concerned with the extent to which the company should be organized functionally as opposed to organizing along modal lines. The author poses the hypothesis that, if the transportation companies are organized along modal lines and each mode is operated as a profit center, the transportation company will not achieve the economics from possible reallocation of traffic from high to low cost carriers that are possible through a functionally organized company. This seems reasonable because the modal profit centers would be attempting to maximize profits in their own areas without regard to the objective of total profit maximization for the firm. As such it seems that a transportation company organized along modal lines would not result in significant economies, as was the case in this study where the objective was total firm-wide profit maximization. Obviously matters are not this simple. One must determine to what extent the organization may be functionally organized. That is, in each functional area, it must be determined the extent to which the operations of the modes can be combined with the object in mind of maximizing the total profits or contribution of the firm as a whole.

Operations--There are several questions that come to mind which must be answered in this area. To what extent can or should maintenance facilities be combined? How will the operating of more than one mode affect the scheduling problems of transportation? What will be the effect on the communications system of the firms? What are the impacts of containerization?

Marketing--What impact will the transportation company have on service offered to customers? How will the formation of transportation companies affect the dependability, frequency, and speed of service? Should the company practice consultative marketing and if so to what extent? What is the importance placed on single carrier service by shippers?

Finance--What new informational burdens will such a company place on the finance and control functions? What types of informational flows will be required?

Labor Relations--Will the unions concerned violently oppose the formation of these companies? How will the top management people be chosen in each functional area?

As indicated above, the list of questions is not a complete list of all matters that must be investigated, but should give the reader an appreciation that a great deal of though must be given to the question of whether a transportation company is managerially feasible. Assuming that these questions can be resolved, how can the knowledge gained from this study be expected to affect the inherent obstacles?

The author would argue that the potential profitability of transportation companies should act to reduce the inherent barriers. Although the vested interests of single modal managements may not entirely disappear, the prospects of increased earnings for stockholders of single modal companies should act to encourage the formation of transportation companies, given that the other obstacles can be overcome.[14]

Relationship to Regulatory Obstacles

In the conduct of this investigation it has been assumed that the I.C.C. would retain the role of protecting the public interest after transportation companies were formed. This is

[14] This proposition is supported, to some extent, by Germane, Glaskowsky, and Heskett when they found that for coordinated transportation if the service is economically sound the carriers will eventually provide the service (*op.cit.*, p. 72).

a completely reasonable assumption.[15] Of more importance is how will the Commission react to the information generated by this study?

The National Transportation Policy (NTP) directs the Commission to promote economical and efficient transportation services while maintaining the inherent advantages of each mode. This study has shown that a transportation company, with the objective of "profit maximization", is economically superior (at least for some test factor combinations) to its single modal counterparts. The transportation company achieves economies by the allocation of the modes to movements for which they are low cost and/or the maximum contribution method of movement. That is the transportation company uses the modes on the route segments in which they have the "inherent advantage".

It is the authors opinion that if the I.C.C. were confronted with such quantitatively documented information the Commission would be hard pressed to deny that such a company would not be "in the public interest".

Relationship to Environmental Obstacles

The major environmental obstacles which may prevent the formation of transportation companies is the contention that the formation of these companies may act to reduce competition

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[15] In the Northern Lines Merger Case (U.S. vs. I.C.C. et.al. 396 U.S. [illegible]) the Supreme Court found that the Congress left to the Commission (I.C.C.) the task of determining if proposed consolidations are 'consistent with the public interest'.

and correspondingly result in the elimination of some facilities and jobs in some locales. It is not clear that the formation of transportation companies would result in less competition in the transportation industry. What has been determined in this study is that a transportation company would use the modes in a different manner than they are being used currently by single modal carriers. The different allocations may require some relocation of facilities but, until the extent of possible economies of scale can be determined, it is not certain that the formation of transportation companies will result in the elimination of facilities, duplicative jobs, and so forth.

It is unlikely that the creation of a transportation company would result in the elimination of facilities, duplicative functions, and so forth, to the same degree that occurs when two carriers of the same mode are merged. At any rate, the I.C.C. is the arbitrator of what is in the public interest and as such must hear the testimony of those who would oppose the formation of transportation companies. To the extent that the creation of such companies would result in the elimination of facilities, jobs and so forth, will determine the opposition to transportation companies by locales, politicians, unions, other competing single modal carriers, and so forth. The end result is that, even though this study has indicated the potential economic advantages of transportation companies, this fact will probably have little impact on the removal of the environmental obstacles. Thus the Commission will have to balance the economic advantages for the transportation companies against the economic sacrifices which some people and locales may suffer.

It must be pointed out that further research is required to determine the extent to which economies of scale may be obtained by forming transportation companies. The greater the economies of scale, the greater the economic benefit to forming companies but correspondingly, the magnitude of the economies of scale are inversely proportional to the economic sacrifice some people and locales will be required to make. That is, the more economies of scale the company achieves, the greater are the reductions of facilities and jobs.

This chapter has placed emphasis on the fact that the economic aspects of common ownership are but one facet of a multidimensional problem. The chapter has not attempted to state all areas of the concept which need future investigation but has attempted to list important areas that require further thought. The following chapter will interpret the results of this study with respect to all the issues of common ownership and present the implications for the future of the concept.

CHAPTER VII

CONCLUSIONS AND IMPLICATIONS OF THE STUDY

The results of the simulation were discussed in Chapter V. Attention was focused on the effects upon the performance measures produced by the test factors. Chapter V also described how the average performance measures differed between the single modal carriers and the transportation company. The analysis was mainly concerned with describing the nature of the effects and discussing the model operations which caused them. Chapter VI identified other aspects of the transportation company concept and related them to the research accomplished in this study. The obstacles which currently bar the establishment of transportation companies in the United States were discussed. Chapter VI also indicated that there was a need for further research (other than economic analysis) on the concept and related the need for this research to some of the critical assumptions made in this project.

The purpose of this chapter is three fold. First the results of the research will be brought together in one convenient place. Secondly, the chapter will indicate future avenues of research which should be pursued. The suggested research presented in this chapter is concerned with extensions of the simulation model. This differs from the research proposals presented in the last chapter which were concerned with matters which were external or not considered in the simulation. Finally the implications of this research project for the real world consideration of transportation companies will be presented.

Summary of the Research

It was found that most of the average differences of the performance measures between the transportation company and the single modal carriers were significant. More specifically, for TL/CL movements it was found that the expected and actual contribution of the transportation company was 11% greater than the sum of these measures for the single modal carriers. In the LTL category of movements, the expected and actual contribution of the transportation company was 17% larger than the combined contributions of the single modal carriers. The transportation company also had the effect of significantly reducing the price paid by shippers for LTL transportation services by 12%.

The prime consideration of the research was the identification and explanation of the manner in which the levels of the test factors affect th average performance measures. The analysis of the effects produced by the six test factors, for each level of the size of shipments parameter, revealed under what operating conditions (test factor levels) the transportation company was "economically superior" to the single modal companies and vice versa.

The major results of the analysis are presented in the following statements:

1. The reduction of the truck operating ratio from 99% to 91% had no main effect on the performance of the transportation company or the single modal carriers.

2. The main effects of a reduction in rail operating ratio from 85% to 65% was to increase the expected and actual contribution of the transportation company compared to that of the single modal companies for both TL/CL and LTL traffic. For TL/CL traffic, this change also had the effect of reducing the total price paid by transportation company users than when this factor was at its high level.

3. The increase in truck load factor from 100 Cwt. to 300 Cwt. acted to increase the price paid by users of the transportation company for both TL/CL and LTL movements. This change also decreased the expected contribution of the transportation company as compared to the single modal companies in the LTL market.

4. The increase in rail load factor from 400 Cwt. to 800 Cwt. served to decrease the difference in expected and actual contribution between the two

organizational approaches. This change also had the effect of reducing the price paid for transportation company customers in the LTL market.

5. The reduction in the amount of capacity available in the system acted to increase the price paid for transportation company users as compared to when this factor was at its high level.

6. The reduction in the amount of traffic constrained to the modes by shippers' logistics constraints acted to increase the expected and actual contribution of the transportation company over that of the single modal carriers for TL/CL movements. This change served to reduce the price paid for transportation by transportation company users for LTL shipments.

7. There were 47 (of 330) significant interaction effects. The manner in which these interaction effects affected the performance measures is graphically displayed in Tables XVIII and XIX in Chapter V.

It must be stressed that the results just described pertain to the analysis of the simulation model per se. That is, these results were obtained from the manipulation of a mathematical model which was formulated to resemble the real world phenomenon. Before these results may be stated as truths research and analysis in the real world is required. It should also be pointed out that the hypothetical nature of the study may be justified by the lack of information on what the economic impact of establishing transportation companies would be.

These results may be restated as a set of working hypotheses that may stand until verified or disproven by real world research. The analysis of the research points to the following hypotheses:

MAJOR HYPOTHESIS--A multimodal transportation company composed of a railroad and trucking company will generate greater contributions to fixed and/or common costs including a profit allowance than its single modal counterparts at the same or lower costs to shippers.

SUB-HYPOTHESIS --(1) The operating ratio of the trucker has no affect on the economic performance of the transportation company.

(2) The operating ratio of the composite railroad directly affects the economic performance of the transportation company. The lower the operating ratio the higher will be the total contribution.

(3) A transportation company with high truck and rail load factors will have a larger contribution than a transportation company with low truck and rail load

factors, if the rate is held constant.

(4) The more traffic is constrained along modal lines by shippers' logistics constraints, the less will be the economic benefits of creating a transportation company.

(5) A transportation company is especially likely to increase the contribution and reduce the total price paid for transportation in the LTL market as compared with single modal operations in this market segment.

Further Research Required

Chapter VI presented the major obstacles which bar the formation of transportation companies in the United States. These were identified as regulatory, inherent, and environmental obstacles. These obstacles were then related to some of the assumptions made in the project. As a result of these obstacles and the assumptions made in the study, it was determined that further research was required to determine the validity of the assumptions and to determine if the obstacles could be overcome. There were several suggestions made for further research in the area of managerial feasibility.

In addition to these research efforts, the nature of the simulation model also suggests other avenues of research. It must be understood that the simulation model itself was the first attempt made in this area to attempt to answer the types of questions addressed in this dissertation. As such, the simulation model was necessarily of a simple construction. The simulation analysis could be enriched by expanding the number and categories of test factors. As explained in Chapter III, environmental and commodity factors were not considered in the thesis. Certainly, enriching the model to consider these factors would advance the model to a more real-world-like abstraction. The model could also be made more complex to involve the real world scheduling problems carriers have to trying to place their equipment at the right time in the right place. Furthermore, the significant interaction effects could be examined to determine which of the aliases caused the significance.

Another subtle and implicit factor which should be brought to the reader's attention is the fact that the simulation was undertaken for a transportation system in which the route structures of the forming companies were parallel. What would be the effect of different route structures on the performance of transportation companies? The author poses the hypothesis that if the route structures of the forming carriers are not approximately parallel or, if the route structure of one carrier does not lie within that of the other, the formation of a transportation company would not result in significant economies. The reasoning behind this is that if the single modal route structures were not parallel, but say end to end, there would be no opportunity for the transportation company to allocate traffic to the low cost mode. Thus in effect a transportation company with this type of route structure would be nothing more than a holding company for two distinct modal oeprations. This question deserves further investigation.

Also this project has been a short run economic analysis. The investigation was conducted on the basis of current operating plant and using the current state-of-the-art technology in transportation. In the past technological developments have played key roles not only in the development of each mode, but also in the manner in which the modes have competed with each other. What relationship will future technological developments have on the multi-modal transportation company? Will future technological developments reduce the economic benefits of transportation companies? Again these are but a few of the unanswered questions concerning common ownership which must be addressed before serious attempts are made to form transportation companies.

Finally, the question of the extent of economies of scale must be addressed. The simulation model could be enriched by allowing for a sensitivity analysis of the fixed and/or common costs to determine the impact of varying degrees of economies of scale. This would allow one to directly ascertain what the effects of the factors are upon profitability of the firms for varying economies of scale.

IMPLICATIONS OF THE STUDY

Although there remain a lot of unanswered questions which must be researched concerning the common ownership question, this study has been a step in the direction of obtaining answers to those questions. It has been pointed out that the results of this study must be verified in the real world. As such the study has served to develop a set of working hypotheses which should be tested in the real world. In other words, it is the author's opinion that the economic benefits of transportation companies, over their single modal counterparts, discovered in this thesis should provide the impetus for a set of experiments involving transportation companies in this country.

If the reader is unconvinced that the results of this dissertation warrant such a deviation from current policy, at the very minimum this dissertation should serve to elevate the concept of transportation companies from the sphere of emotional and sometimes illogical arguments that have surrounded the concept for years. The main contribution of this dissertation may then be considered to be that of introducing the concept of systems analysis to this important issue in transportation. As such this dissertation should serve as impetus for more meaningful dialogue and research on the subject.

BIBLIOGRAPHY

Books

Baumol, William J., Economic Theory and Operations Analysis, Second Edition, (Englewood Cliffs, N.J.: Prentice-Hall, Inc.) 1965.

Bonini, Charles P., Simulation of Information and Decision Systems in the Firm., "The Ford Foundation Doctoral Dissertation Series", (Englewood Cliffs, N.J.: Prentice-Hall, Inc.) 1963.

Bowersox, Donald J., Smykay, Edward W., and LaLonde, Bernard J., Physical Distribution Management, (New York: The MacMillan Company) 1968.

Churchman, C. West, Ackoff, Russel L., and Arnoff, E. Leonard, Introduction to Operations Research, (New York: John Wiley and Sons, Inc.) 1957.

Cochran, William G., and Cox, Gertrude M., Experimental Designs, (New York: John Wiley and Sons, Inc.) 1950.

Dixon, Wilfrid J., and Massey, Frank J., Jr., Introduction to Statistical Analysis., (New York: McGraw-Hill, Inc.) 1969.

Fellmeth, Robert C., The Interstate Commerce Omission: The Public Interest and the I.C.C. (The Ralph Nader Study Group Report on the Interstate Commerce Commission and Transportation), (New York: Grossman Publishers) 1970.

Gass, Saul I., Linear Programming Methods and Applications, Third Edition, (New York, N.Y.: McGraw-Hill Book Company, Inc.) 1969.

Germane, Gayton E., Glaskowsky, Nicholas A., Jr., Heskett, J. L., Highway Transportation Management, (New York, N.Y.: McGraw-Hill Book Company, Inc.) 1963.

Guenther, William C., Analysis of Variance, (Englewood Cliffs, N.J.: Prentice-Hall, Inc.) 1964.

Guenther, William C., Concepts of Statistical Inference, (New York: McGraw-Hill Book Company, Inc.) 1965.

Hadley, G., *Nonlinear and Dynamic Programming*, (Reading, Mass.: Addison-Wesley Publishing Co., Inc.) 1964.

Heskett, J. L., Ivie, Robert M., and Glaskowsky, Nicholas A., Jr., *Business Logistics - Management of Physical Supply and Distribution*, (New York, N.Y.: The Ronald Press Co.) 1964.

Hicks, Charles R., *Fundamental Concepts in the Design of Experiments*, (New York: Holt, Rinehart and Winston, Inc.) 1964.

Hillier, Frederick S. and Lieberman, Gerald J., *Introduction to Operations Research*, (San Francisco, Calif.: Holden-Day, Inc.) 1969.

Hoel, Paul G., *Introduction to Mathematical Statistics*, Third Edition, (New York: John Wiley and Sons, Inc.) 1962.

Hunter, Holland, *Soviet Transport Experience: Its Lessons for Other Countries*, Transport Research Program, (Washington, D.C.: The Brookings Institution) 1963.

Locklin, D. Philip, *Economics of Transportation*, Sixth Edition, (Homewood, Ill.: Richard D. Irwin, Inc.) 1966.

McMillan, Claude, Jr., *Mathematical Programming: An Introduction to the Design and Application of Optimal Decision Machines* (New York: John Wiley and Sons, Inc.) 1970.

Meier, Robert C., Newell, William T., and Pazer, Harold L., *Simulation in Business and Economics*, (Englewood Cliffs, N.J.: Prentice-Hall, Inc.) 1969.

Mendenhall, William, *The Design and Analysis of Experiments*, (Belmont, Calif.: Wadsworth Publishing Company, Inc.) 1968.

Meyer, John R., Peck, Merton, J., Stenason, John, and Zwick, Charles, *The Economics of Competition in the Transportation Industries*, (Cambridge, Mass.: Harvard University Press) 1969.

Naylor, Thomas H., Balintfy, Joseph L., Burdick, Donald S., and Chu, Kong, *Computer Simulation Techniques*, (New York, N.Y.: John Wiley and Sons, Inc.) 1967.

Norton, Hugh S., *Modern Transportation Economics*, (Columbus, Ohio: Charles E. Merrill Books, Inc.) 1963.

Pegrum, Dudley F., *Transportation: Economics and Public Policy*, Revised Edition, (Homewood, Ill.: Richard D. Irwin, Inc.) 1968.

Sampson, Roy A. and Farris, Martin T., Domestic Transportation: Practice Theory and Policy, Second Edition, (Boston, Mass.: Houghton Mifflin Company) 1971.

Taff, Charles A., Commercial Motor Transportation, Fourth Edition, (Homewood, Ill.: Richard D. Irwin, Inc.) 1969.

Transportation Economics, A Conference of the Universities - National Bureau Committee for Economic Research, National Bureau of Economic Research, (New York: Columbia University Press) 1965.

Wagner, Harvey M., Principles of Operations Research, (Englewood Cliffs, N.J.: Prentice-Hall, Inc.) 1969.

Articles and Reports

"'A Better Class of Traffic' Is Needed for New Growth", Railway Age, (May 31, 1971), pp. 27-28.

"American Trucking Trends 1970-71", Departments of Research and Transport Economics and Public Relations, American Trucking Associations, Inc., 1971.

Baker, Charles D., "Railroad Needs: More Apparent than Real?", Transportation and Distribution Management, (May 1971), p. 43.

Beckmann, Martin, "A Continuous Model of Transportation", Econometrica, Vol. 20, No. 4, (October 1952), pp. 643-660.

Bickerton, Richard L., "Self-Help for the Railroads", Transportation and Distribution Management, (May 1971), pp. 29-32.

Bickerton, "Time to Plan", Transportation and Distribution Management, (December 1970), pp. 23-24.

Campanella, Frank, "On the Right Track", Barrons, XLVIII (October 28, 1968), p. 9.

Dodge, William H., "The Dilemma of Intermodal Rate Competition", I.C.C. Practitioners Journal, XXXVI (July August 1969), pp. 1801-1815.

Dodge, William H., "The Inherent Advantages of Carrier Modes Under the National Transportation Policy", Land Economics, XLIV (November 1968), pp. 492-502.

Douglas, Peter S., "The Economic Irrelevance of 'Common Ownership'", I.C.C. Practitioners Journal, XXVI, (July-August 1969), pp. 1794-1800.

Doyle, John P., "A Transportation System", Distribution Manager, (December 1968), pp. 35-42.

Harbeson, Robert W., "The Supreme Court and Intermodal Rate Competition", I.C.C. Practitioners Journal, XXXVI, (March-April 1969), pp. 1487-1495.

Harbeson, Robert W., "Recent Trends in the Regulation of Intermodal Rate Competition in Transportation", Land Economics, XLII, (August 1969), pp. 315-326.

Houser, Fred, "Putting Profit into Piggyback", Railway Age, (May 31, 1971), pp. 29-31.

Levine, Harvey A., "The Railroad Industry's Experience Under Section 15a (3) of the Transportation Act of 1958", I.C.C. Practitioners Journal, XXXV, (January-February 1968), pp. 252-266.

Naylor, Thomas H. and Finger, J. M., "Verification of Computer Simulation Models", Management Science, XIV, (October 1967), pp. 92-101.

Nupp, Byron, "Regulatory Standards in Common Ownership in Transportation", I.C.C. Practitioners Journal, XXXIV, (November-December 1966), pp. 21-37.

Nightingale, Edmund A., "A Critique of American Transportation Policy Developments", Third Annual American Transportation Research Forum, Pittsburgh, Pennsylvania, December 29, 1962.

"Panel Discussion: The Effect of Diversification into Other Modes of Transportation", I.C.C. Practitioners Journal, XXXVI, (September-October 1969), pp. 1989-2011.

"Piggybackers All Fall Down But Railroads Look for Pickup", Business Week, (November 22, 1969), p. 158.

Rays, J. M. W., "A Selection Problem of Share Fixed Costs and Network Flows", Management Science, Vol. 17, No. 3, (November 1970), pp. 200-207.

Suelflow, James E., Hille, Stanley J., "The Transportation Company: An Economic Argument for Intermodal Ownership", Land Economics, (August 1970), pp. 275-286.

"The Astro Plan for Progress", Transportation and Distribution Management, (May 1971), pp. 38-39.

"Transportation Facts and Trends", Transportation Association of America, Washington, D.C., Quarterly Supplement, January 1971.

Tucker, William H., "Wanted: The Air - Truck - Rail - Water - Bus Company", Columbia Journal of World Business II, (November-December 1967), pp. 47-54.

"Vore Asks Intermodal Carrier Experiment, Creedy Favors Replacement-Cost Rate Base", Traffic World, (May 17, 1971), pp. 35-36.

Williams, Ernest W., Jr., "Traffic Composition and Railroad Earning Power", Transportation Journal, Vol. 9, No. 1, (Fall 1969), pp. 17-21.

"Yearbook of Railroad Facts", 1970 Edition, Economic and Finance Department, Association of American Railroads, April 1970.

Government Documents

"Explanation of the Development of Motor Carrier Costs with Statement as to Their Meaning and Significance", I.C.C. Statement No. 4-59, Washington, D. C., 1959.

"Explanation of Rail Cost Finding Procedures and Principles Relating to the Use of Costs", I.C.C. Statement No. 7-63, Washington, D. C., 1963.

"Eighty-Third Annual Report on Transport Statistics in the United States for the Year Ended December 31, 1969", I.C.C., GPO, Washington, D.C., 1970.

"Message on Transportation", (President Kennedy's Message), 87th Congress, 2nd Session, House of Representatives Document No. 384, Washington, D.C., April 5, 1962.

The Interstate Commerce Act, U. S. Government Printing Office, Washington, D. C., 1968.

U. S. Congress House of Representatives, Committee on Armed Services, Adequacy of Transportation Systems in Support of the National Defense Effort in Event of Mobilization Hearings before a Subcommittee under authority of H. Res. 19, 86th Congress, 1st Session, 1959.

U. S. Congress Senate Committee on Interstate and Foreign Commerce, Common Ownership by Regulated Carriers Hearings before the Surface Transportation Subcommittee on S. 452, S. 1353, 1354, 1355, 2189, 86th Congress, 1st Session, 1961.

U. S. Congress Senate Committee on Commerce, National Transportation Policy, S. Rept. 445, 87th Congress, 1st Session, 1961.

Unpublished Materials

Chervany, Norman Lee, A Simulation Analysis of Cash Flow Patterns Within a Manufacturing Organization, unpublished D.B.A. dissertation, Graduate School of Business, Indiana University, 1968.

Glaskowsky, Nicholas A., Jr., An Analysis and Evaluation of the Development of Coordinated Air-Truck Transportation, with Special Reference to Northwest Airlines, Inc., unpublished Ph.D. dissertation, Graduate School, Stanford University, 1960.

Hay, G. A., Morlok, E. K., and Charnes, A., "Toward Optimal Planning of a Two-Mode Urban Transportation System: A Linear Programming Formulation," The Transportation Center at Northwestern University, Evanston, Illinois, 1965 (mimeographed).

Morlok, E. K., Nihan, N. L., and Sullivan, R. F., "A Multiple-Mode Transportation Network Design Model," The Transportation Center at Northwestern University, Evanston, Illinois, 4 Volumes, 1969 (mimeographed).

APPENDIX 1

A. THE t TEST INVOLVING PAIRED OBSERVATIONS OF TWO POPULATION MEANS

To determine if the mean differences between the performance measures of the transportation company minus those of the single modal carriers were statistically significant, a t test involving paired observations was utilized. This test was used because the observations (from each simulation run) of the performance measures for each organizational alternative are related to one another. That is, the random components and parametric values were held constant across the organizational alternatives for one run and varied between runs. Thus, the observations occurred in pairs.

The exact hypothesis which was tested for each performance measure was:

$$H_0: \; y_d = 0$$
$$H_1: \; y_d \neq 0$$

where d_y is the mean difference of the particular transportation company performance measure minus the performance measures of the single modal companies.

The null hypothesis was rejected if

$$t_{n-1}(\frac{\alpha}{2}) \geq \frac{\bar{d} - y_d}{s_d} \cdot \sqrt{n} \geq t_{n-1}(1 - \frac{\alpha}{2})$$

where t_{n-1} is the t statistic with n - 1 degrees of freedom associated with a particular level of significance α,

$$\bar{d} = \frac{\sum_{i=1}^{n} d_i}{n},$$

$$d_i = X_{mi} - (X_{Ti} + X_{Ri}),$$

X_{mi}, X_{Ti}, X_{Ri} = one observation of a particular performance measure of the multi-modal transportation company, single modal trucker, and railroad, respectively,

$$s_d^2 = \frac{\sum_{i=1}^{n} (d_i - \bar{d})^2}{n - 1}$$

n = the number of paired observations which was <u>32</u> for both the TL and LTL category of movement.[1]

B. THE ANALYSIS OF VARIANCE OF THE MAIN AND FIRST-ORDER INTERACTION EFFECTS

The fixed effects analysis of variance (ANOVA) model was used in this dissertation to determine if the main and first-order interaction effects were statistically significant. The ANOVA technique is based on the fact that the total sum of squares deviation from the mean observation can be partitioned into the

[1]The reader is referred to Guenther, op.cit., pp. 24-26 for a more detailed discussion of this test.

sum of squares associated with the main effects, interaction effects, and error.[2]

Mathematically the ANOVA model used in this project is as follows:

$$
\begin{aligned}
SST = {} & SSA + SSB + SSC + SSD + SSE + SSF + \\
& SSAB + SSAC + SSAD + SSAE + \\
& SSAF + SSBC + SSBD + SSBE + \\
& SSBF + SSCD + SSCE + SSCF + \\
& SSDE + SSDF + SSEF + SSE
\end{aligned}
$$

where SST = total sum of squares,

SSA, SSB, SSC, SSD, SSE, SSF = sum of squares associated with each main effect,

SSAB, SSAC, SSAD, SSAE, SSAF, SSBC, SSBD, SSBE, SSBF, SSCD, SSCE, SSCF, SSDE, SSDF, SSEF = sum of squares associated with the respective interaction effects

SSE = sum of squares associated with the error term

The test statistic utilized in the analysis of variance to determine if the null hypotheses concerning the main and first order interaction effects should be rejected is the F ratio.

The F ratio is simply the mean square of the treatment of interest (MST) divided by the mean square error (MSE). The mean squares are simply the sum of the squares of each term identified above divided by the appropriate degrees of freedom (df). If

[2] See for instance, Mendenhall, *op. cit.*, Chapter 8.

the F ratio is greater than the $F_{r_1 r_2}(1 - \alpha)$ statistic the null hypothesis that the factor had no effect is rejected. r_1 and r_2 are the degrees of freedom in the numerator and denominator of the F ratio.

The ANOVA data obtained in this study for the TL/CL expected profit performance measure is presented in Table XX for the interested reader. The degrees of freedom are the same for each of the other performance measures.[3]

[3] The computational formulas for the sum of squares may be found in Guenther, Hicks, or Mendenhall.

TABLE XX

ANOVA FOR TL/CL EXPECTED PROFIT

Source of Variation	degrees of freedom	Sum of Squares	F ratio
A	1	86,064	.00024
B	1	2,487,612,862	7.06678**
C	1	77,484,194	.22012
D	1	2,928,671,473	8.31974**
E	1	778,271,971	2.21091
F	1	8,977,039,915	25.50187***
AB	1	77,054,877	.21890
AC	1	491	.00000
AD	1	7,202,549	.02046
AE	1	631,307,171	1.79341
AF	1	9,119,695	.02591
BC	1	790,168,790	2.24470
BD	1	2,625,748,262	7.45920**
BE	1	214,529,719	.60943
BF	1	1,032,111,683	2.93201
CD	1	17,847,982	.05070
CE	1	1,613,393,219	4.58331*
CF	1	6,116,315	.01738
DE	1	80,086,535	.22751
DF	1	1,946,189,605	5.52871**
EF	1	44,227,059	.12564
ERROR	10	3,520,149,339	
TOTAL	31		

*Significant at the 10% level

**Significant at the 5% level

***Significant at the 1% level

APPENDIX 2

A. FLOWCHART OF THE SIMULATION MODEL

A verbal describption of the simulation model has been presented in the text of this study. Thus, discussion of the simulator will not be included in the appendix. In the discussion of the simulation model, the flowchart of the model was not included to increase the readability of the project. For the interested reader, the flowchart of the simulator is presented in Figure 3.

B. THE SIMULATION COMPUTER PROGRAM

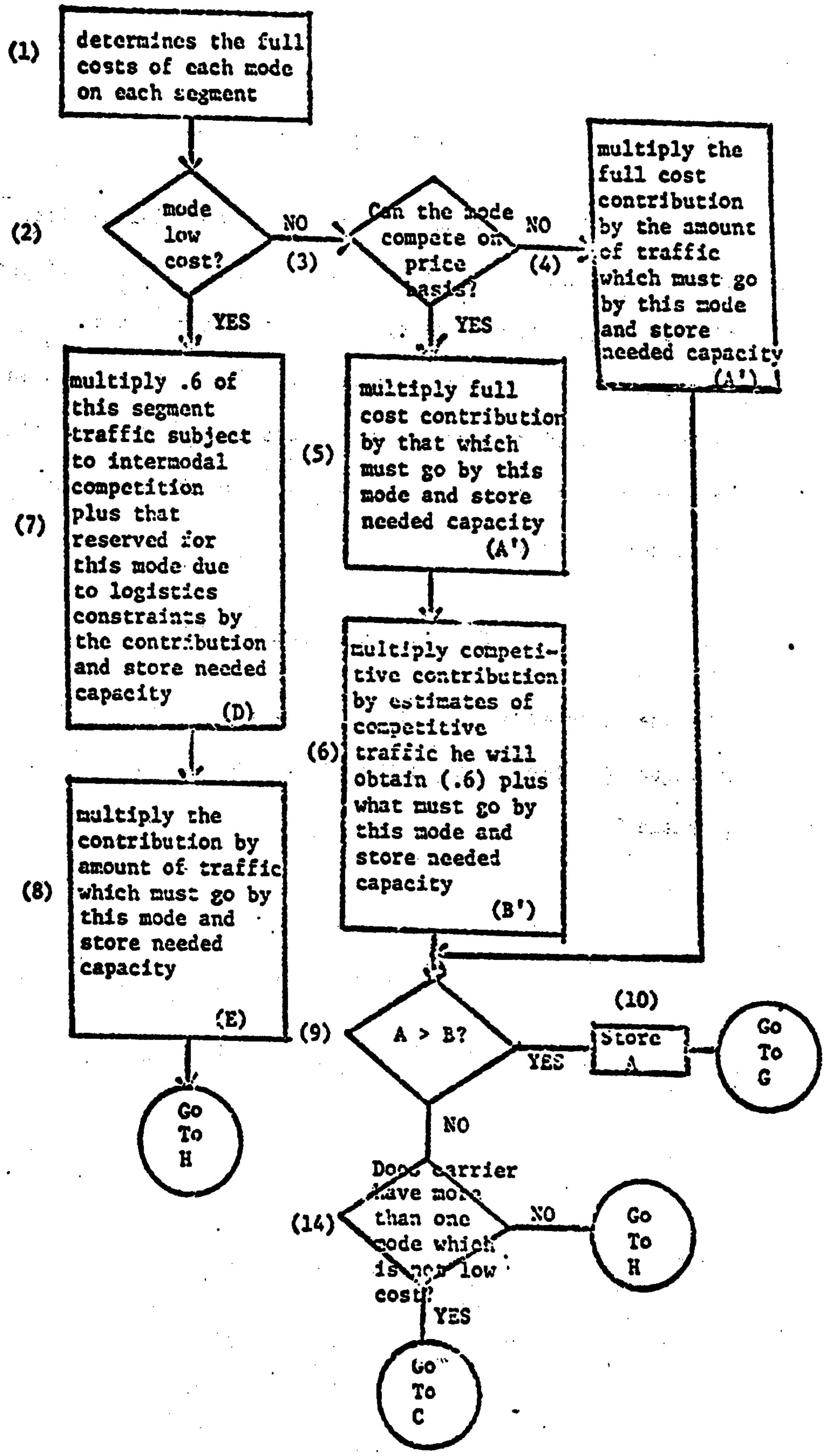
The computer program of the simulation model is presented in Figure 4. The coding is written in the OMNITAB computer language.[1]

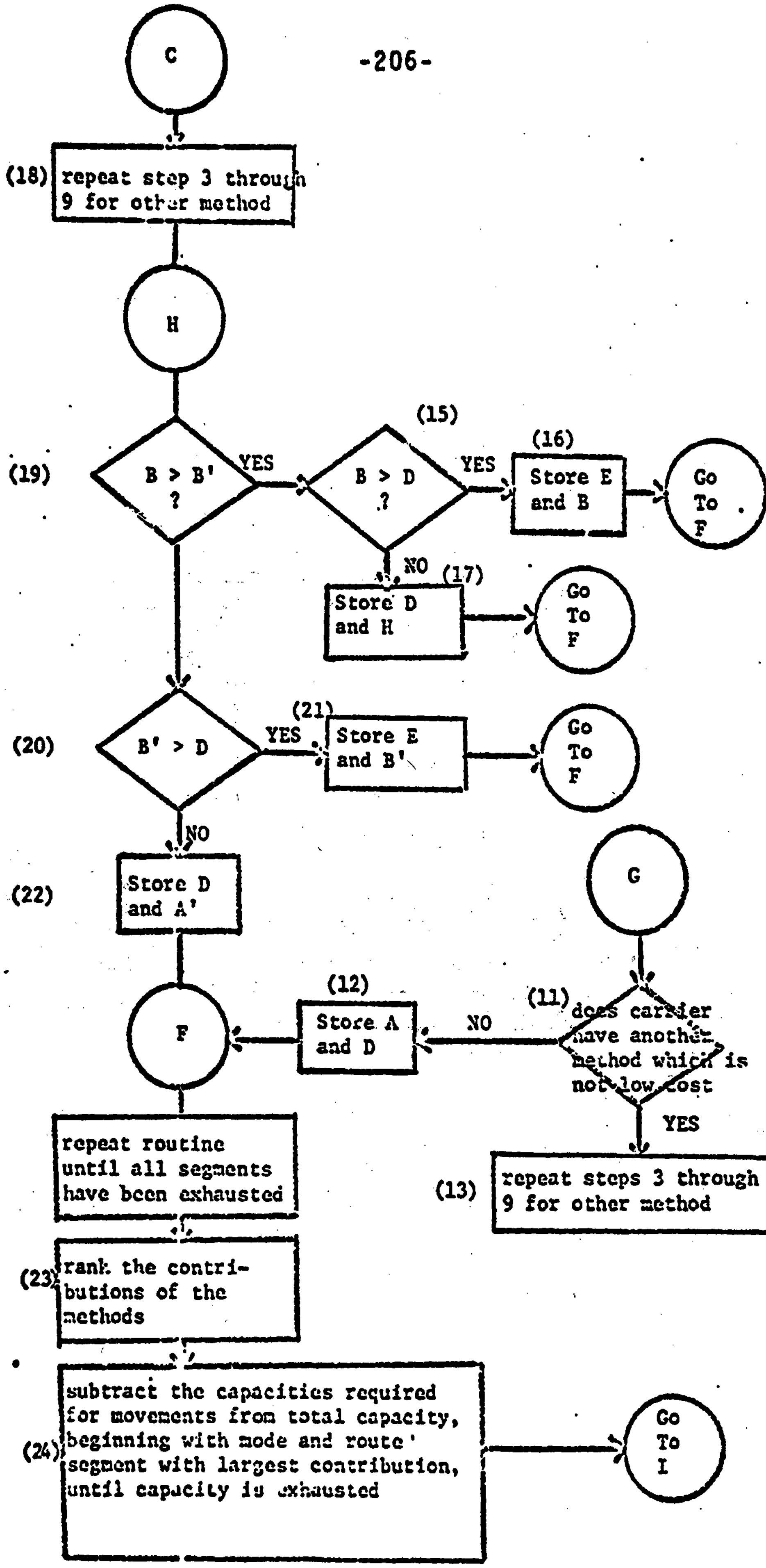
---

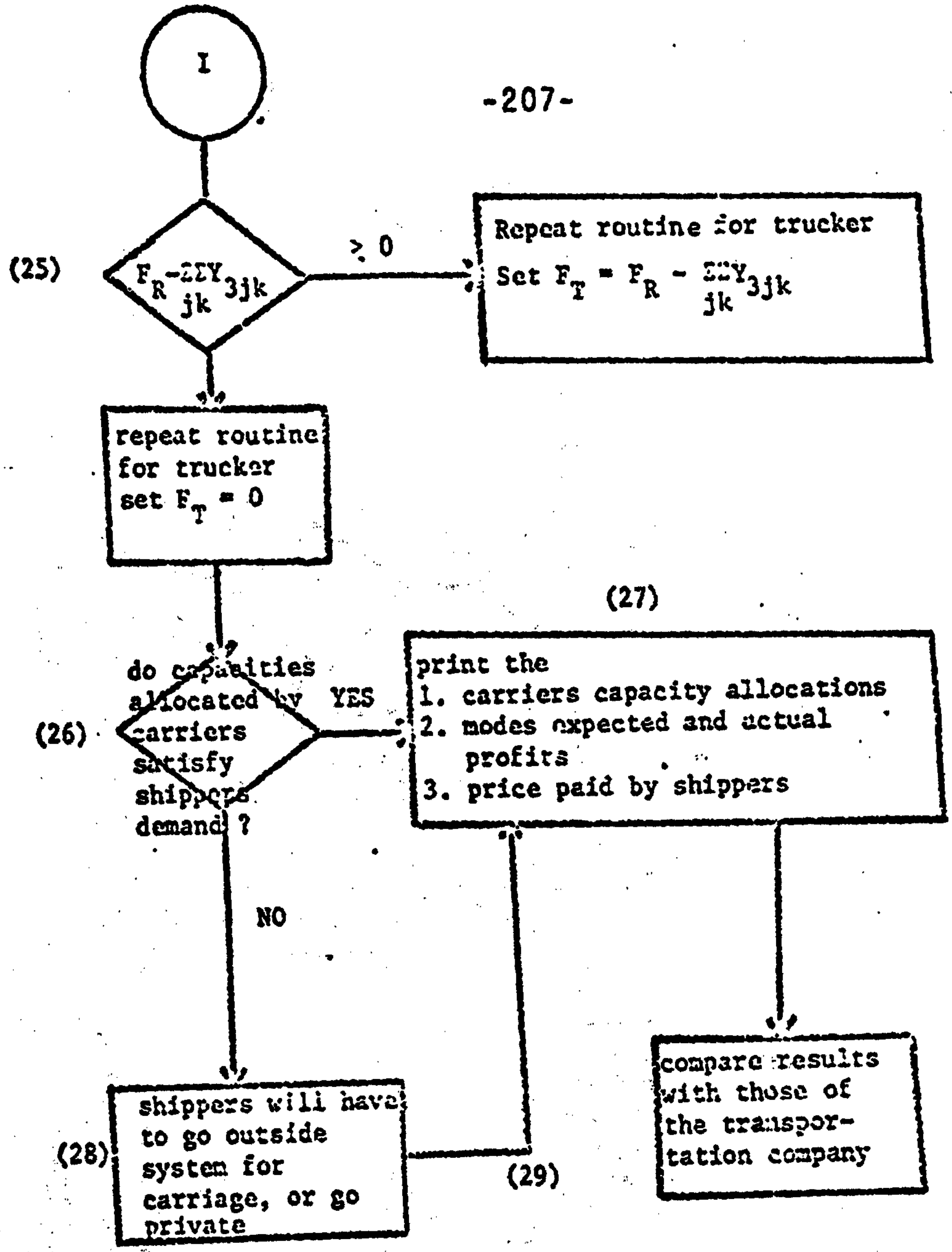
[1] David Hogben, Sally T. Peavy, and Ruth N. Varner, OMNITAB II User's Reference Manual, United States Department of Commerce, National Bureau of Standards, October 1971.

Figure 3

Flowchart For Simulation Model




C
(18) repeat step 3 through 9 for other method
H
(19) B > B' ?
YES
(15) B > D ?
YES
(16) Store E and B
Go To F
NO
(17) Store D and H
Go To F
(20) B' > D
YES
(21) Store E and B'
Go To F
NO
(22) Store D and A'
G
(11) does carrier have another method which is not low cost
NO
(12) Store A and D
F
YES
(13) repeat steps 3 through 9 for other method
repeat routine until all segments have been exhausted
(23) rank the contributions of the methods
(24) subtract the capacities required for movements from total capacity, beginning with mode and route segment with largest contribution, until capacity is exhausted
Go To I



I
(25)
$F_R - \sum\sum_{jk} Y_{3jk}$
≥ 0
Repeat routine for trucker
Set $F_T = F_R - \sum\sum_{jk} Y_{3jk}$
repeat routine for trucker set $F_T = 0$
(26)
do capacities allocated by carriers satisfy shippers demand ?
YES
NO
(27)
print the
1. carriers capacity allocations
2. modes expected and actual profits
3. price paid by shippers
(28)
shippers will have to go outside system for carriage, or go private
(29)
compare results with those of the transportation company

Figure 4

LIST OF COMMANDS, DATA AND DIAGNOSTICS

The Simulation Computer Program

```
LIST 2
DIMENSION 10 500
FIXED 2
READ 1,2,3,4
.547 .082 .163 .024
.418 .042 .125 .019
.5987 .0442 0.0 .0211
.5504 .0774 0.0 .0192
1/MULTIPLY 1 .125 5
2/MULTIPLY 1 .250 6
3/MULTIPLY 1 .375 7
4/MULTIPLY 1 .5 8
5/MULTIPLY 1 .75 9
6/MULTIPLY 1 .875 10
7/MULTIPLY 1 1.0 11
8/MULTIPLY 1 1.5 12
9/MULTIPLY 1 1.75 13
10/MULTIPLY 1.875 1 14
PERFORM 1 10
AMULTIPLY 3,5 2X10 2.0 3,5
AMOVE 1,2 4X13 1,79
ADIVIDE 1,2 2X13 1.3333 1,2
11/ROWSUM 5,2,3,4 15
12/ROWSUM 6,2,3,4 16
13/ROWSUM 7,2,3,4 17
14/ROWSUM 8,2,3,4 18
15/ROWSUM 9,2,3,4 19
16/ROWSUM 10,2,3,4 20
17/ROWSUM 11,2,3,4 21
18/ROWSUM 12,2,3,4 22
19/ROWSUM 13,2,3,4 23
20/ROWSUM 14,2,3,4 24
21/ADIVIDE 1,15 2X10 .8 1,25
22/ADIVIDE 3,15 2X10 .9 3,25
23/ADIVIDE 1,25 1X10 .85 1,35
24/ADIVIDE 2,25 1X10 .65 1,45
25/ADIVIDE 3,25 1X10 .99 1,55
26/ADIVIDE 4,25 1X10 .91 1,65
27/ASUBTRACT 1,35 1X10 1,25 2,35
28/ASUBTRACT 1,45 1X10 2,25 2,45
29/ASUBTRACT 1,55 1X10 3,25 2,55
30/ASUBTRACT 1,65 1X10 4,25 2,65
31/ASUBTRACT 1,25 1X10 1,15 3,35
32/ASUBTRACT 2,25 1X10 2,15 3,45
33/ASUBTRACT 3,25 1X10 3,15 3,55
34/ASUBTRACT 4,25 1X10 4,15 3,65
35/AMOVE 1,15 1X10 4,35
36/AMOVE 2,15 1X10 4,45
37/AMOVE 3,15 1X10 4,55
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
38/AMOVE 4,15 1X10 4,65
39/AMOVE 1,5 1X10 5,35
40/AMOVE 2,5 1X10 5,45
41/AMOVE 3,5 1X10 5,55
42/AMOVE 4,5 1X10 5,65
43/ATRANSPOSE 1,2 4X3 1,75
44/DEMOTE  5 75 35 75 36 75 37 75 38  75 39 75 40 75 41 75 42 75 43 75 44
45/DEMOTE 5 76 45 76 46 76 47 76 48 76 49 76 50 76 51 76 52 76 53 76 54
46/DEMOTE 5 77 55 77 56 77 57 77 58 77 59 77 60 77 61 77 62 77 63 77 64
47/DEMOTE 5 78 65 78 66 78 67 78 68 78 69 78 70 78 71 78 72 78 73 78 74
48/RESET NRMAX 8
PERFORM  11  48
AMOVE 1,35 8X40 1,101
AMOVE 1,79 4X13 1,2
ADIVIDE 1,2 2X13 .6666 1,2
ADIVIDE 3,2 2X13 .5 3,2
PERFORM  11  48
AMOVE 1,35 8X40 1,141
READ 1,2,3,4
.547 .0066 .0163 .024
.418 .0033 .0132 .019
0.0 .0842 0.0 .0211
0.0 .0774 0.0 .0192
PERFORM 1 10
ADIVIDE 1,2 2X13 1.3333 1,2
ADIVIDE 1,5 2X10 .75 1,5
AMOVE 1,2 4X13 1,79
PERFORM 11 48
AMOVE 1,35 8X40 1,181
AADD 1,35 8X10 1,55 1,221
AADD 1,35 8X10 1,65 1,231
AADD 1,45 8X10 1,55 1,241
AADD 1,45 8X10 1,65 1,251
AMOVE 1,79 4X13 1,2
ADIVIDE 1,2 2X13 .6666 1,2
ADIVIDE 3,2 2X13 .5 3,2
ADIVIDE 1,5 2X10 .5  1,5
PERFORM  11  48
AMOVE 1,35 8X40 1,261
AADD 1,35 8X10 1,55 1,301
AADD 1,35 8X10 1,65 1,311
AADD 1,45 8X10 1,55 1,321
AADD 1,45 8X10 1,65 1,331
AADD 1,181 8X10 1,291 1,341
AADD 1,181 8X10 1,291 1,351
AADD 1,191 8X10 1,281 1,361
AADD 1,191 8X10 1,291 1,371
AADD 1,261 8X10 1,201 1,381
AADD 1,271 8X10 1,211 1,391
AADD 1,271 8X10 1,201 1,401
```

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LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
AADD 1,271 8X10 1,211 1,411
49/ATRANSPOSE 1,101 1X10 1,1
50/INCREMENT 49 0,20 0X0 0,6
PERFORM 49 50 16
51/ATRANSPOSE 4,101 1X10 1,65
52/INCREMENT 51 0,10 0X0 0,6
PERFORM 51 52 32
DIMENSION 40 125
RESET NRMAX 10
INSERT 2 7 2 2 49
INSERT 49 7 3 3 49
INSERT 49 1 4 4 49
INSERT 4 11 2 2 50
INSERT 50 11 3 3 50
INSERT 50 3 4 4 50
INSERT 4 13 2 2 51
INSERT 51 13 3 3 51
INSERT 51 1 4 4 51
INSERT 2 15 2 2 52
INSERT 52 15 3 3 52
INSERT 52 3 4 4 52
INSERT 19 17 2 2 53
INSERT 20 17 2 2 54
INSERT 19 18 2 2 55
INSERT 20 18 2 2 56
INSERT 23 21 2 2 57
INSERT 24 21 2 2 58
INSERT 23 22 2 2 59
INSERT 24 22 2 2 60
INSERT 23 17 2 2 61
INSERT 24 17 2 2 62
INSERT 23 18 2 2 63
INSERT 24 18 2 2 64
INSERT 19 21 2 2 65
INSERT 20 21 2 2 66
INSERT 19 22 2 2 67
INSERT 20 22 2 2 68
61/INSERT 53 29 3 2 53
62/INCREMENT 61 1 1 0 0 1
PERFORM 61 62 4
RESTORE 61 53 29 4 2 53
PERFORM 61 62 4
63/INSERT 57 37 3 2 57
64/INCREMENT 63 1 1 0 0 1
PERFORM 63 64 12
RESTORE 63 57 37 4 2 57
PERFORM 63 64 12
AMOVE 1,5   10X2 1,100
AMOVE 1,9   10X2 1,102
AMOVE 1,25  10X4 1,104
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
AMOVE 1,33  10X6 1,108
AMOVE 1,49 40X20 1,1
AERASE 1,21 40X79
AMOVE 1,2 40X1 1,26
AMOVE 1,9 40X1 1,27
AMOVE 1,102 10X1 1,44
ASUBTRACT 1,102 10X1 1,108 1,48
ASUBTRACT 1,103 10X1 1,110 1,49
SET 28
1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4
SET 29
1 1 1 1 2 2 2 2 3 3 3 3 4 4 4 4 5 5 5 5 6 6 6 6 7 7 7 7 8 8 8 8 9 9 9 9 10 10 10
SET 40 29
10
SET 30
25200 6000 4800 33600 13200 3600 2400 16800 26400 7200 6000 34800 36000 7200
SET 15 30
9000 52200 37800 9000 7200 50400 37800 9000 7200 50400 37800 9000 10800 54000
SET 29 30
36000 7200 9000 52200 25200 6000 6000 34800 37800 9000 7200 50400
SET 31
19200 0 0 28800 9600 0 0 14400 19200 0 0 28800 28800 0 0 43200 28800 0 0 43200
SET 21 31
28800 0 0 43200 28800 0 0 43200 28800 0 0 43200 19200 0 0 28800 28800 0 0 43200
SET 65
30000 0 10800 39000 15600 0 6000 20400 32400 0 13200 42000 45000 0 16200 59400
SET 17 65
45000 0 16200 59400 45000 0 16200 59400 40600 0 19800 63000 45000 0 16200 59400
SET 33 65
31200 0 12000 40800 45000 0 16200 59400
ADD 360000. 23 112
ADD 480000. 23 113
ADD 600000. 23 114
ADD 600000. 23 115
ADD 180000. 23 116
ADD 240000. 23 117
ADD 300000. 23 118
ADD 300000. 23 119
AMOVE 1,112 40X8 1,71
72/AMOVE 1,26 4X2 1,37
73/INCREMENT 72 4,0 0X0 0,0
74/RESET 4
75/MINIMUM 37 40
76/AMOVE 1,28 4X4 1,32
77/INCREMENT 76 4,0 0X0 0,0
78/SUBTRACT 36 37 41
79/SUBTRACT 38 40 42
80.5/ADIVIDE 1,44 1X1 2,37 1,44
80.9/INCREMENT 80.5 1,0 0X0 0,0 0,0
81/AMULTIPLY 1,44 1X1 2,42 1,45
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
82/ASUBTRACT 2,42 1X1 1,45 1,46
85/AMOVE 1,45 1X1 2,42
86.5/AMOVE 1,48 1X1 2,41
86.6/INCREMENT 86.5 1,0 0X0 0,0
87/MULTIPLY 41 35 36
88/MULTIPLY 42 34 39
89/AMOVE 2,32 3X8 1,50
90/INCREMENT 89 0,0 0X0 3,0
91/AMOVE 1,46 1X1 2,42
92.5/AMOVE 1,49 1X1 2,41
92.6/INCREMENT 92.5 1,0 0X0 0,0
93/MULTIPLY 41 35 36
94/MULTIPLY 42 34 39
95/AMOVE 1,32 2X8 1,58
96/INCREMENT 95 0,0 0X0 2,0
PERFORM 72 96 10
AMOVE 1,85 40X1 1,30
RESTORE 76 1,28 4X4 1,32
RESTORE 72 1,28 4X2 1,37
97/PERFORM 72 79
98/PERFORM 87 88
99/AMOVE 1,32 4X8 1,77
99.1/INCREMENT 99 0,0 0X0 4,0
PERFORM 97 99.1 10
SET 97
1 0 0 2 0 0 3 0 0 4 0 0 5 0 0 6 0 0 7 0 0 8 0 0 9 0 0 10 0 0
SET 98
0 1 0 2 0 3 0 4 0 5 0 6 0 7 0 8 0 9 0 10
100/RESET 40
100.1/ERASE 120 121
100.2/PARSUM 53 120
100.3/PARSUM 61 121
100.4/DUPLICATE 40 40,120  1X2 1,120
100.5/SUBTRACT 120 73 73
100.6/SUBTRACT 121 74 74
100.7/AMOVE 1,71 40X4 1,87
100.8/AMOVE 1,57 30X1 1,21
100.9/SUBTRACT 56 57 57
PERFORM 100 100.9
RESET 30
101/MAXIMUM 57 66 50 67 51 68 52 69 53 70
101.1/ERASE 99
101.2/IFNE 67 2,0
101.3/MATCH 57 66 57 99
101.4/MATCH 57 99 0,0 57
108/SUBTRACT 76 72 72
109/ERASE 76
110/MATCH 99 66 21 56
111/MATCH 99 66 52 53
112/MATCH 53 68 0,0 57
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
112.1/IFNE 67 3.0
112.2/MATCH 57 66 57 99
112.3/MATCH 57 99 0.0 57
112.4/IFLE 71 0.0
112.5/IFLE 72 0.0
112.6/SUBTRACT 70 69 76
112.7/SUBTRACT 76 71 71
112.8/PERFORM 108 112
113/IFNE 67 4.0
114/MATCH 57 66 57 99
115/MATCH 57 99 0.0 57
116/IFLE 73 0.0
116.1/SUBTRACT 70 69 76
116.2/SUBTRACT 76 73 73
117/PERFORM 107 112
118/PERFORM 101 101.4
118.1/PERFORM 112.1 112.8
119/PERFORM 113 117
119.1/IFLE 57 0.0
PERFORM 118 119.1 30
ERASE  66 67 68 69 70 75 76
RESET 20
119.4/AMOVE 1.65 20X1 1.22
119.5/SUBTRACT 62 65 65
PERFORM 119.4 119.5
120/MAXIMUM 65 66 58 67 59 68 60 69 61 70 98 96
120.1/ERASE 99
120.2/IFNE 67 2.0
120.3/MATCH 98 96 65 99
120.4/MATCH 98 96 0.0 65
121/IFLE 72 0.0
122/IFLE 74 0.0
123/SUBTRACT 70 69 76
125/SUBTRACT 76 72 72
126/SUBTRACT 76 74 74
127/MATCH 99 66 22 62
128/MATCH 99 66 60 61
128.1/MATCH 59 68 0.0 65
128.3/RESET 30
128.4/AMOVE 1.96 10X1 21.96
128.7/MATCH 97 96 21 54
129.1/MATCH 97 96 52 53
129.2/RESET 20
129.4/IFNE 67 1.0
129.5/MATCH 65 66 65 99
129.6/MATCH 65 99 0.0 65
130/IFLE 74 0.0
131/SUBTRACT 70 69 76
133/SUBTRACT 76 74 74
134/PERFORM 127 128.1
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
135/PERFORM 120 129.2
136/PERFORM 129.4 134
136.1/IFLE 65 0.0
PERFORM 135 136.1 20
PARSUM 62 123
HEAD 50/ RAIL MODES
HEAD 51/  ROUTE
HEAD 52/ EST MARKET
HEAD 53/ADJ EST MKT
HEAD 54/ EST PROFIT
HEAD 125/CUM EST PFT
HEAD 55/UNADJ RATE
HEAD 58/TRUCK MODES
HEAD 59/  ROUTE
HEAD 60/ EST MARKET
HEAD 61/ADJ EST MKT
HEAD 62/ EST PROFIT
HEAD 123/CUM EST PFT
HEAD 63/UNADJ RATE
HEAD 77/TRAN CO MODE
HEAD 78/  ROUTE
HEAD 79/ EST MARKET
HEAD 80/ADJ EST MKT
HEAD 81/ EST PROFIT
HEAD 124/CUM EST PFT
HEAD 82/UNADJ RATE
PRINT 58 59 60 61 62 123 63
RESET 30
PARSUM 54 122
PRINT 50 51 52 53 54 122 55
RESET 40
ERASE  66 67 68 69 70 75 76
137/ADEFINE 2,77 148 0.0
138/INCREMENT 137 4.0 0X0 0.0
PERFORM 137 138 10
AMOVE 1,87 40X4 1,71
AADD 1,71 40X1 1,74 1,71
138.3/AMOVE 1,84 40X1 1,24
138.4/SUBTRACT 81 84 84
PERFORM 138.3 138.4
139/MAXIMUM 84 66 77 67 78 68 79 69 80 70
139.1/ERASE 99
139.2/IFNE 67 3.0
139.3/MATCH 84 66 84 99
139.4/MATCH 84 66 0.0 84
140/IFLE 71 0.0
141/IFLE 72 0.0
142/SUBTRACT 70 69 70
144/SUBTRACT 76 71 71
145/SUBTRACT 76 72 72
```

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LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
146/ERASE 76
147/MATCH 99 66 24 81
148/MATCH 99 66 79 80
149/MATCH 78 68 0.0 84
149.1/IFNE 67 4.0
149.2/MATCH 84 66 84 99
149.3/MATCH 84 99 0.0 84
150/IFLE 73 0.0
151/SUBTRACT 70 69 76
153/SUBTRACT 76 73 73
154/PERFORM 147 149
154.1/IFNE 67 1.0
154.2/MATCH 84 66 84 99
154.3/MATCH 84 99 0.0 84
155/IFLE 71 0.0
156/SUBTRACT 70 69 76
158/SUBTRACT 76 71 71
159/PERFORM 147 149
160/PERFORM 139 149
161/PERFORM 149.1 154
162/PERFORM 154.1 159
162.1/IFLE 86 0.8
PERFORM 160 162.1 30
PARSUM 81 124
PRINT 77 78 79 80 81 124 82
163/RESTORE 72 1.26 4X2 1.37
163.5/RESTORE 86.5 1.44 1X1 2.37 1.44
163.6/RESTORE 86.5 1.48 1X1 2.41
166/RESTORE 76 1.28 4X4 1.32
167/RESTORE 89 2.32 3X8 1.50
169/RESTORE 95 1.32 2X8 1.58
169.5/RESTORE 92.5 1.49 1X1 2.41
170/RESTORE 99 1.32 4X8 1.77
171/RESTORE 137 2.77 1X8 0.0
172/PERFORM 163 171
176/PERFORM 72 96 10
177/AMOVE 1.85 40X1 1.30
178/PERFORM 163 164
179/PERFORM 97 99.1 10
179.1/PERFORM 100 100.9
180/RESET 30
181/PERFORM 118 119.1 30
183/ERASE 66 67 68 69 70 75 76
184/RESET 20
184.1/PERFORM 119.4 119.5
185/PERFORM 135 136.1 20
185.1/PARSUM 62 123
186/PRINT 58 59 60 61 62 123 63
186.1/RESET 30
186.2/PARSUM 54 122
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
186.3/PRINT 50 51 52 53 54 122 55
187/RESET 40
188/ERASE 66 67 68 69 70 75 76
189/PERFORM 137 138 10
190/AMOVE 1,87 40X4 1,71
191/AADD 1,71 40X4 1,74 1,71
191.1/PERFORM 138.3 138.4
192/PERFORM 160 162.1 30
192.1/PARSUM 81 124
193/PRINT 77 78 79 80 81 124 82
AMOVE 1,1 40X1 1,26
AMOVE 1,8 40X1 1,27
AMOVE 1,100 10X1 1,44
ASUBTRACT 1,100 10X1 1,105 1,48
ASUBTRACT 1,101 10X1 1,107 1,49
AMOVE 1,112 40X4 1,71
SET 30
36000 7200 9000 52200 39600 10800 10800 54000 39600 10800 7200 50400 39600 10800
SET 15 30
10800 54000 39600 10800 10800 54000 39600 10800 10800 54000 37800 9000 7200
SET 28 30
50400 13200 3600 3000 17400 26400 7200 6000 34800 12600 3600 2400 16800
SET 31
28800 0 0 43200 28800 0 0 43200 28800 0 0 43200 28800 0 0 43200 28800 0 0 43200
SET 21 31
28800 0 0 43200 28800 0 0 43200 9600 0 0 14400 19200 0 0 28800 9600 0 0 14400
SET 85
45000 0 16200 59400 50400 0 21000 64800 46800 0 18000 61200 50400 0 21000 64800
SET 17 85
50400 0 21000 64800 50400 0 21000 64800 45000 0 16200 59400 16200 0 6600 21000
SET 33 85
32400 0 13200 42000 15000 0 5400 19800
PERFORM 172 193
AMOVE 1,102 10X1 1,44
ASUBTRACT 1,102 10X1 1,109 1,48
ASUBTRACT 1,101 10X1 1,106 1,49
AMOVE 1,4 40X1 1,26
AMOVE 1,10 40X1 1,27
AMOVE 1,116 40X4 1,71
SET 30
43200 36000 36000 40800 33600 28800 24000 31200 12000 9600 9600 13200 33600
SET 14 30
28800 28600 36000 16800 14400 12000 15600 12000 9600 9600 13200 28800 24000
SET 27 30
19200 26400 16800 14400 12000 15600 28800 24000 25800 36000 36000 28800 36000
SET 40 30
46800
SET 31
7200 0 0 10800 4800 0 0 7200 2400 0 0 3600 4800 0 0 7200 2400 0 0 3600 2400 0 0
SET 24 31
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
3600 4800 0 0 7200 2400 0 0 3600 4800 0 0 7200 7200 0 0 10800
SET 85
79200 0 72000 82800 57600 0 52800 60000 21400 0 19200 22800 62400 0 57600 64800
SET 17 85
28800 0 26400 30000 21600 0 19200 22800 57600 0 52800 60000 28800 0 26400 30000
SET 33 85
57600 0 52800 60000 72000 0 64800 75600
PERFORM 172 193
AMOVE 1,100 10X1 1,44
ASUBTRACT 1,100 10X1 1,104 1,48
ASUBTRACT 1,103 10X1 1,111 1,49
AMOVE 1,3 40X1 1,26
AMOVE 1,14 40X1 1,27
AMOVE 1,116 40X4 1,71
SET 30
33600 28800 19200 26400 50400 43200 28800 39600 12000 9600 9600 13200 12000 9600
SET 15 30
9600 13200 28800 24000 28800 36000 28800 24000 24000 31200 12000 9600 9600 13200
SET 29 30
16800 14400 9600 13200 14400 12000 12000 15600 16800 14400 9600 13200
SET 31
4800 0 0 7200 7200 0 0 10800 2400 0 0 3600 2400 0 0 3600 4800 0 0 7200 4800 0 0
SET 24 31
7200 2400 0 0 3600 2400 0 0 3600 2400 0 0 3600 2400 0 0 3600
SET 85
52800 0 48000 55200 79200 0 72000 82800 21600 0 19200 22800 21600 0 19200 22800
SET 17 85
57600 0 52800 60000 52800 0 48000 55200 21600 0 19200 22800 26400 0 24000 27600
SET 33 85
26400 0 24000 27600 26400 0 24000 27600
PERFORM 172 193
AMOVE 1,102 10X1 1,44
ASUBTRACT 1,102 10X1 1,109 1,48
ASUBTRACT 1,101 10X1 1,107 1,49
AMOVE 1,4 40X1 1,26
AMOVE 1,20 40X1 1,27
AMOVE 1,116 40X4 1,71
SET 30
36000 7200 9000 52200 12600 3000 2400 16800 12000 2400 3600 18000 39600 19800
SET 15 30
10800 54000 25200 6000 7200 36000 12600 3000 2400 16800 24400 7200 6000 34800
SET 29 30
12000 2400 2400 16800 25200 6000 4800 33600 13200 3600 3400 18000
SET 31
28800 0 0 43200 9600 0 0 14400 9600 0 0 14400 24800 0 0 43200 19200 0 0 28800
SET 21 31
9600 0 0 14400 19200 0 0 28800 9600 0 0 14400 19200 0 0 28800 9600 0 0 14400
SET 85
45000 0 16200 59400 15000 0 5400 19800 15600 0 6000 20400 50400 0 21600 64800
SET 17 85
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
32400 0 13200 42000 15000 0 5400 19800 32400 0 13200 42000 14400 0 4800 19200
SET 33 85
36000 0 10800 39600 16800 0 7200 21600
PERFORM 172 193
AMOVE 1,100 10X1 1,44
ASUBTRACT 1,109 10X1 1,104 1,48
ASUBTRACT 1,103 10X1 1,110 1,49
AMOVE 1,3 40X1 1,26
AMOVE 1,13 40X1 1,27
AMOVE 1,116 40X4 1,71
SET 30
26400 7200 7200 36000 37800 9000 9000 52200 36000 7200 10800 54000 36000 7200
SET 15 30
10800 54000 20400 7200 4800 33600 24000 4800 4800 33600 12600 3000 2400 16800
SET 29 30
26400 7200 6000 34800 26400 7200 4800 33600 36000 7200 7200 50400
SET 31
19200 0 0 28800 28800 0 0 43200 28800 0 0 43200 28800 0 0 43200 19200 0 0 28800
SET 21 31
19200 0 0 28800 9600 0 0 14400 19200 0 0 28800 19200 0 0 28800 28800 0 0 43200
SET 85
33600 0 14400 43200 46800 0 15600 61200 46800 0 18000 61200 45800 0 18000 61200
SET 17 85
31200 0 12000 40800 28800 0 9600 38400 15000 0 5400 19800 32400 0 13200 42000
SET 33 85
31200 0 12000 40800 43200 0 14400 57600
PERFORM 172 193
AMOVE 1,102 10X1 1,44
ASUBTRACT 1,107 10X1 1,108 1,48
ASUBTRACT 1,103 10X1 1,111 1,49
AMOVE 1,2 40X1 1,26
AMOVE 1,10 40X1 1,27
AMOVE 1,112 40X4 1,71
SET 30
14800 14400 14400 18000 16800 14400 14400 18000 26400 24000 24000 31200 33600
SET 14 30
28800 19200 26400 50400 43200 36000 46800 16800 14400 12000 15600 14400 12000
SET 27 30
12000 15600 33600 28800 28800 36000 16800 14400 14400 18000 16800 14400 14400
SET 40 30
18000
SET 31
2400 0 0 3600 2400 0 0 3600 4800 0 0 7200 4800 0 0 7200 7200 0 0 10800 2400 0 0
SET 24 31
3600 2400 0 0 3600 4800 0 0 7200 2400 0 0 3600 2400 0 0 3600
SET 85
31200 0 28800 32400 31200 0 28800 32400 52800 0 48000 55200 52800 0 48000 55200
SET 17 85
86400 0 79200 90000 28800 0 26400 30000 26400 0 24000 27600 62400 0 57600 66800
SET 33 85
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
31200 0 28400 32400 31200 0 25800 32400
PERFORM 172 193
AMOVE 1,100 10X1 1,44
ASUBTRACT 1,103 10X1 1,105 1,48
ASUBTRACT 1,101 10X1 1,106 1,49
AMOVE 1,1 40X1 1,26
AMOVE 1,7 40X1 1,27
AMOVE 1,112 40X4 1,71
SET 30
43200 36000 28800 39000 24000 19200 28800 36000 10800 14400 12000 15600 50400
SET 14 30
43200 43200 54000 50400 43200 28800 39600 14400 12000 14400 18000 36000 28800
SET 27 30
28800 39600 43200 36000 30000 46800 12000 9600 9600 13200 50400 43200 36000
SET 40 30
46800
SET 31
7200 0 0 10800 4800 0 0 7200 2400 0 0 3600 7200 0 0 10800 7200 0 0 10800 2400 0
SET 23 31
0 3600 7200 0 0 10800 7200 0 0 10800 2400 0 0 3600 7200 0 0 10800
SET 85
72000 0 64800 74600 52800 0 48000 55200 28800 0 26400 30000 93600 0 86400 97200
SET 17 85
79200 0 72000 82800 28300 0 26400 30000 64800 0 57600 68400 79200 0 72000 82600
SET 33 85
21600 0 19200 22800 46400 0 79200 90000
PERFORM 172 193
AMOVE 1,102 10X1 1,44
ASUBTRACT 1,102 10X1 1,109 1,48
ASUBTRACT 1,103 10X1 1,111 1,49
AMOVE 1,2 40X1 1,26
AMOVE 1,12 40X1 1,27
AMOVE 1,112 40X4 1,71
SET 30
37600 9000 9000 52200 36000 7200 9000 52200 37600 10800 9000 52200 12000 2400
SET 15 30
3600 10800 25200 6000 7200 36900 12600 3000 3600 18000 39600 10800 7200 40400
SET 29 30
12000 2400 2400 10800 37800 9000 10800 54000 25400 7200 7200 36000
SET 31
28800 0 0 43200 28800 0 0 43200 28800 0 0 43200 9600 0 0 14400 19200 0 0 28800
SET 21 31
9600 0 0 14400 28800 0 0 43200 9600 0 0 14400 28800 0 0 43200 19200 0 0 28800
SET 85
64800 0 18000 61200 45000 0 16200 59400 48600 0 19800 63000 15600 0 6000 20400
SET 17 85
32400 0 13200 42000 16200 0 6600 21000 46800 0 18000 61200 14400 0 4900 19200
SET 33 85
64800 0 19800 63000 33600 0 14400 43200
PERFORM 172 193
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
AMOVE 1,100 10X1 1,46
ASUBTRACT 1,100 10X1 1,104 1,46
ASUBTRACT 1,101 10X1 1,106 1,49
AMOVE 1,1 40X1 1,25
AMOVE 1,5 40X1 1,27
AMOVE 1,112 40X4 1,71
SET 30
12600 3000 3000 17400 26400 7200 7200 36000 39600 10800 10800 54000 12600 3000
SET 15 30
2400 16800 12600 3000 3000 17400 36000 7200 7200 50400 39600 10800 10800 54000
SET 29 30
26400 7200 7200 36000 36000 7200 10800 54000 36000 7200 7200 50400
SET 31
9600 0 0 14400 19200 0 0 28800 28800 0 0 43200 9600 0 0 14400 9600 0 0 14400
SET 21 31
28800 0 0 43200 28800 0 0 43200 19200 0 0 28800 28800 0 0 43200 28800 0 0 43200
SET 85
15600 0 6000 20400 33600 0 14400 43200 50400 0 21600 64800 15600 0 5400 19800
SET 17 85
15600 0 6000 20400 43200 0 14400 57600 50400 0 21600 64800 50400 0 21600 64800
SET 33 85
46800 0 18000 61200 43200 0 14400 57600
PERFORM 172 193
AMOVE 1,102 10X1 1,46
ASUBTRACT 1,102 10X1 1,108 1,48
ASUBTRACT 1,101 10X1 1,107 1,49
AMOVE 1,6 40X1 1,26
AMOVE 1,18 40X1 1,27
AMOVE 1,116 40X4 1,71
SET 30
36000 28800 28800 39600 14400 12000 12000 15600 16800 14400 9600 13200 24000
SET 14 30
19200 28800 36000 36000 28800 43200 54000 43200 30000 43200 54000 28800 24000
SET 27 30
19200 26400 24000 19200 19200 26400 43200 36000 28800 39600 16800 14400 14400
SET 40 30
18000
SET 31
7200 0 0 10800 2400 0 0 3600 2400 0 0 3600 4800 0 0 7200 7200 0 0 10800 7200 0 0
SET 24 31
10800 4800 0 0 7200 4800 0 0 7200 7200 0 0 10800 4800 0 0 7200
SET 85
64800 0 57600 60400 26400 0 24000 27600 26400 0 24000 27600 52800 0 48000 55200
SET 17 85
79200 0 72000 82800 86400 0 79200 90000 49000 0 43200 50400 43200 0 38400 45600
SET 33 85
72000 0 64800 75600 82400 0 57600 64800
PERFORM 172 193
AMOVE 1,103 10X1 1,46
ASUBTRACT 1,109 10X1 1,105 1,46
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
ASUBTRACT 1,103 10X1 1,110 1,49
AMOVE 1,3 40X1 1,26
AMOVE 1,15 40X1 1,27
AMOVE 1,110 40X4 1,71
SET 30
38300 28800 28800 39600 10800 14400 12000 15600 36000 28800 43200 54000 12000
SET 14 30
9600 12000 15600 43200 36000 36300 46800 16800 14400 14400 10800 28400 24000
SET 27 30
28800 36000 36000 28800 30000 46800 33600 28800 20400 36000 24000 19200 28800
SET 40 30
36000
SET 31
7200 0 0 10800 2400 0 0 3600 7200 0 0 10800 2400 0 0 3600 7200 0 0 10800 2400 0
SET 23 31
0 3600 4800 0 0 7200 7200 0 0 10800 4800 0 0 7200 4800 0 0 7200
SET 45
64800 0 57600 88400 28800 0 26400 30000 79200 0 72000 82800 24000 0 21600 25200
SET 17 45
79200 0 72000 82800 31200 0 28800 32400 57600 0 52400 60000 72000 0 64800 75600
SET 33 45
62400 0 57600 64800 52800 0 46800 55200
PERFORM 172 193
AMOVE 1,102 10X1 1,44
ASUBTRACT 1,107 10X1 1,108 1,48
ASUBTRACT 1,101 10X1 1,106 1,49
AMOVE 1,3 40X1 1,26
AMOVE 1,17 40X1 1,27
AMOVE 1,110 40X4 1,71
SET 30
26400 7200 6000 24000 12600 3600 3600 18000 37800 9600 10800 54000 36000 7200
SET 15 30
9600 52200 28800 7200 4800 33600 26400 7200 7200 30000 34800 10800 10800 54000
SET 29 30
12000 2400 3600 18000 12000 2400 2400 16800 37800 9600 7200 50400
SET 31
19200 0 0 28800 4800 0 0 14400 28800 0 0 43200 28800 0 0 43200 19200 0 0 28800
SET 21 31
19200 0 0 28800 28800 0 0 43200 9600 0 0 14400 9600 0 0 14400 28800 0 0 43200
SET 45
37400 0 13200 42000 16200 0 66600 21000 49500 0 19800 63000 45600 0 14200 59400
SET 17 45
31200 0 17000 40800 33600 0 14400 43200 50400 0 21600 44800 15600 0 6000 20400
SET 33 45
14400 0 4800 19200 43000 0 16200 59400
PERFORM 172 193
AMOVE 1,109 10X1 1,44
ASUBTRACT 1,100 10X1 1,105 1,48
ASUBTRACT 1,103 10X1 1,111 1,49
AMOVE 1,3 40X1 1,26
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
AMOVE 1.18 40X1 1.27
AMOVE 1.116 40X4 1.71
SET 30
26400 7200 7200 36000 26400 7200 4800 33600 12000 2400 3600 18000 26400 7200
SET 15 30
4800 36800 26400 7200 7200 36000 12600 3000 2400 16800 12600 3000 2400 16800
SET 29 30
12600 3000 3600 18000 13200 3600 2400 16800 26400 7200 4800 33600
SET 31
19200 0 0 28800 19200 0 0 28800 9600 0 0 14400 19200 0 0 28800 19200 0 0 28800
SET 21 31
9600 0 0 14400 9600 0 0 14400 9600 0 0 14400 9600 0 0 14400 19200 0 0 28800
SET 85
33600 0 14400 43200 31200 0 12000 40800 15600 0 6000 20400 32400 0 13200 42000
SET 17 85
33600 0 14400 43200 15000 0 5400 19800 15000 0 5400 19800 10200 0 6600 21000
SET 33 85
15600 0 6000 20400 31200 0 12000 40800
PERFORM 172 193
AMOVE 1.102 10X1 1.44
ASUBTRACT 1.102 10X1 1.109 1.48
ASUBTRACT 1.103 10X1 1.110 1.49
AMOVE 1.2 40X1 1.26
AMOVE 1.11 40X1 1.27
AMOVE 1.112 40X4 1.71
SET 30
16800 14400 9600 13200 30000 28800 43200 54000 26400 19200 28800 36000 50400
SET 16 30
43200 28800 39600 16800 14400 14400 18000 39600 26400 43200 54000 15600 14400
SET 27 30
12000 15600 36000 28800 28800 39600 24000 19200 13200 26400 50400 43200 28800
SET 40 30
30600
SET 31
2400 0 0 3600 7200 0 0 10800 4800 0 0 7200 7200 0 0 10800 2400 0 0 3600 7200 0 0
SET 24 31
10800 2400 0 0 3600 7200 0 0 10800 4800 0 0 7200 7200 0 0 10800
SET 85
26400 0 24000 27000 79200 0 72000 82800 52800 0 44300 55200 79200 0 72000 82800
SET 17 85
31200 0 28800 32400 79200 0 72000 82800 28300 0 26400 30000 64800 0 57600 69400
SET 33 85
43200 0 38400 45600 79200 0 72000 82800
PERFORM 172 193
AMOVE 1.100 10X1 1.44
ASUBTRACT 1.100 10X1 1.104 1.48
ASUBTRACT 1.101 10X1 1.107 1.49
AMOVE 1.1 40X1 1.26
AMOVE 1.4 40X1 1.27
AMOVE 1.112 40X4 1.71
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
SET 30
14400 14400 9600 13200 14400 12000 9600 13200 16800 14400 9600 13200 14400 12000
SET 15 30
14400 18000 33600 28800 19200 26400 28800 24000 24000 31200 33300 28800 19200
SET 24 30
26400 43200 36000 28800 39600 16800 14400 14400 18000 28800 24000 19200 26400
SET 31
2400 0 0 3600 2400 0 0 3600 2400 0 0 3600 2400 0 0 3600 4800 0 0 7200 4800 0 0
SET 24 31
7200 4800 0 0 7200 7200 0 0 13800 2400 0 0 3600 4800 0 0 7200
SET 85
26400 0 24000 27600 24000 0 21600 25200 26400 0 24300 27600 26800 0 26400 30000
SET 17 85
57600 0 52800 60000 52800 0 49000 55200 52800 0 48000 55200 72000 0 44800 75600
SET 33 85
31200 0 28800 32400 48000 0 43200 50400
PERFORM 172 193
AMOVE 1,102 10X1 1,46
ASUBTRACT 1,102 10X1 1,108 1,48
ASUBTRACT 1,101 10X1 1,107 1,49
AMOVE 1,6 40X1 1,26
AMOVE 1,18 40X1 1,27
AMOVE 1,112 40X4 1,71
SET 30
12000 2400 3000 18000 12600 3000 3600 18000 12600 3000 3600 17400 12000 2400
SET 15 30
2400 18000 37800 9000 7200 50400 12000 2400 2600 18000 25200 6000 4800 33600
SET 29 30
25200 6000 7200 30000 12000 2400 3000 17400 12600 3000 3000 17400
SET 31
9600 0 0 14400 9600 0 0 14400 9600 0 0 14400 9600 0 0 14400 28800 0 0 43200
SET 21 31
9600 0 0 14400 19200 0 0 28800 19200 0 0 28800 9600 0 0 14400 9600 0 0 14400
SET 85
15600 0 6000 20400 10200 0 6600 21600 15600 0 6000 20400 14400 0 4800 19200
SET 17 85
45000 0 16200 59400 15600 0 6000 20400 30000 0 10800 39600 32400 0 13200 42000
SET 33 85
15000 0 5400 15900 15600 0 6000 20400
PERFORM 172 193
AMOVE 1,100 10X1 1,44
ASUBTRACT 1,100 10X1 1,105 1,48
ASUBTRACT 1,103 10X1 1,110 1,49
AMOVE 1,3 40X1 1,26
AMOVE 1,15 40X1 1,27
AMOVE 1,112 40X4 1,71
SET 30
36000 7200 7200 50400 24000 4800 6000 34800 25200 6000 6000 34800 25200 6000
SET 15 30
6000 34800 36000 7200 10800 54000 39600 10800 9600 57200 39000 7200 9600 57200
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
SET 29 30
36000 1200 9600 52200 36000 7200 10800 54000 26400 7200 6000 34800
SET 31
28800 0 0 43200 19200 0 0 28800 19200 0 0 28800 19200 0 0 28800 28800 0 0 43200
SET 21 31
28800 0 0 43200 28800 0 0 43200 28800 0 0 43200 28800 0 0 43200 19200 0 0 28800
SET 45
43200 0 14400 57600 28800 0 10800 39600 31200 0 12000 46800 31200 0 12000 40800
SET 17 45
43200 0 18000 61200 43200 0 19800 63000 45000 0 14400 59400 45000 0 14400 59400
SET 23 45
43200 0 18000 61200 32400 0 13200 42000
PERFORM 172 193
AMOVE 1,102 10*1 1,44
ASUBTRACT 1,102 10*1 1,109 1,48
ASUBTRACT 1,103 10*1 1,111 1,49
AMOVE 1,2 40*1 1,26
AMOVE 1,12 40*1 1,27
AMOVE 1,116 40*4 1,71
SET 30
28800 24000 28800 36000 12000 9600 12000 15600 28800 24000 28800 36000 33600
SET 14 30
28800 19200 28800 14400 12000 14400 18000 28800 24000 24000 31200 12000 9600
SET 27 30
9600 13200 24000 19200 28800 36000 16800 14400 9600 13200 16800 14400 9600
SET 46 30
13200
SET 31
4800 0 0 7200 2400 0 0 3600 4800 0 0 7200 4800 0 0 7200 2400 0 0 3600 4800 0 0
SET 24 31
7200 2400 0 0 3600 4800 0 0 7200 2400 0 0 3600 2400 0 0 3600
SET 45
57600 0 52800 60000 24000 0 21600 25200 57600 0 52800 60000 52800 0 48000 55200
SET 17 45
28800 0 26400 30000 52800 0 48000 55200 21600 0 19200 22800 52800 0 48000 55200
SET 43 45
26400 0 24000 27600 26400 0 24000 27600
PERFORM 172 193
AMOVE 1,100 10*1 1,44
ASUBTRACT 1,100 10*1 1,104 1,48
ASUBTRACT 1,101 10*1 1,106 1,49
AMOVE 1,1 40*1 1,26
AMOVE 1,5 40*1 1,27
AMOVE 1,119 40*4 1,71
SET 30
43200 36000 28800 39600 16800 14400 12000 15600 33600 28800 19200 26400 16800
SET 14 30
14400 12000 15600 50400 43200 36000 46800 43200 36000 28800 39600 24000 19200
SET 27 30
24000 31200 36000 28800 36000 46800 12000 9600 9600 13200 36000 28800 43200
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
SET 40 30
54000
SET 41
7200 0 0 10800 2400 0 0 3000 4800 0 0 7200 2400 0 0 3000 7200 0 0 10800 7200 0 0
SET 26 31
10800 4800 0 0 7200 7200 0 0 10800 2400 0 0 3600 7200 0 0 10800
SET 45
72000 0 64800 75000 28800 0 26400 30000 52800 0 48000 55200 28800 0 25000 30000
SET 17 45
86400 0 79200 90000 72000 0 94800 75500 48000 0 43200 50400 72000 0 86400 75600
SET 33 45
21600 0 19200 22400 79200 0 72000 82800
PERFORM 172 193
ABOVE 1.102 10X1 1.44
ASUBTRACT 1.102 10X1 1.109 1.48
ASUBTRACT 1.103 10X1 1.110 1.49
ABOVE 1.2 40X1 1.26
ABOVE 1.11 40X1 1.27
ABOVE 1.115 40X6 1.71
SET 30
26400 7200 6000 34800 13200 3600 2400 16800 12000 2400 3600 10800 37800 9000
SET 15 30
14400 54000 30000 7200 7200 50400 13200 3600 2400 16800 24000 4800 6000 34800
SET 29 30
24000 4800 7200 30000 26400 7200 6000 34800 26400 7200 7200 30000
SET 31
19200 0 0 28800 9000 0 0 14400 9600 0 0 14400 24800 0 0 43200 28800 0 0 43200
SET 21 31
9600 0 0 14400 19200 0 0 28800 19200 0 0 28800 19200 0 0 28800 19200 0 0 28800
SET 45
32400 0 13200 42000 15600 0 9000 20400 15600 0 9000 20400 40500 0 19400 43000
SET 17 45
43200 0 16800 57000 15000 0 9000 29400 30000 0 10800 39600 31200 0 12000 43800
SET 33 45
32400 0 13200 42000 43600 0 14400 43200
PERFORM 172 193
ABOVE 1.103 10X1 1.44
ASUBTRACT 1.100 10X1 1.104 1.48
ASUBTRACT 1.101 10X1 1.107 1.49
ABOVE 1.1 40X1 1.26
ABOVE 1.5 40X1 1.27
ABOVE 1.110 40X6 1.71
SET 30
39600 10800 10800 54000 12000 3000 3500 19900 25200 6000 6000 34800 13200 3600
SET 15 30
3600 16800 37800 9010 9300 32200 12000 2400 2400 16800 13200 3500 2400 16800
SET 29 30
39600 10800 10800 54000 12000 2400 3600 19100 25200 6000 6000 34800
SET 41
28800 0 0 43200 9000 0 0 14400 19200 0 0 28800 9600 0 0 14400 28800 0 0 43200
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
SET 21 31
9600 0 0 14400 9600 0 0 14400 28800 0 0 43200 9600 0 0 14400 19200 0 0 28800
SET 35
57600 0 21600 64800 16200 0 9600 21000 31200 0 12000 40800 15600 0 6000 20400
SET 17 85
46800 0 18000 61200 14400 0 4800 19200 15600 0 6000 20400 50400 0 21600 64800
SET 33 85
15600 0 6000 20400 31200 0 12000 40800
PERFORM 172 193
AMOVE 1,102 10X1 1,44
ASUBTRACT 1,102 10X1 1,108 1,48
ASUBTRACT 1,101 10X1 1,106 1,49
AMOVE 1,4 40X1 1,26
AMOVE 1,17 40X1 1,27
AMOVE 1,112 40X4 1,71
SET 30
43200 36000 28800 39600 33600 28800 19200 25400 33600 28800 26800 36000 12000
SET 14 30
9600 12000 15600 14400 12000 9600 13200 36000 20800 43200 54000 28800 24000
SET 27 30
19200 25600 14400 12000 9600 13200 36000 23800 36000 45600 36000 28800 28800
SET 40 30
39600
SET 31
7200 0 0 10800 4800 0 0 7200 4800 0 0 7200 2400 0 0 3600 2400 0 0 3600 7200 0 0
SET 24 31
10800 4800 0 0 7200 2400 0 0 3600 7200 0 0 10800 7200 0 0 10800
SET 45
72000 0 64800 75600 52800 0 48000 55200 62400 0 57600 64800 24000 0 21600 25200
SET 17 85
24000 0 21600 25200 79200 0 72000 82800 48000 0 43200 50400 24000 0 21600 25200
SET 33 85
72000 0 64800 75600 64800 0 57600 68400
PERFORM 172 193
AMOVE 1,100 10X1 1,44
ASUBTRACT 1,100 10X1 1,105 1,48
ASUBTRACT 1,103 10X1 1,111 1,49
AMOVE 1,3 40X1 1,26
AMOVE 1,15 40X1 1,27
AMOVE 1,112 40X4 1,71
SET 30
14800 14400 12000 15600 12000 9600 12000 15600 43200 36000 43200 54000 50400
SET 14 30
43200 43200 54000 24000 19200 28800 36000 14400 12000 14400 18000 33600 28800
SET 27 30
28800 36000 24000 19200 24000 31200 33600 28800 19200 26400 14400 12000 9600
SET 40 30
13200
SET 31
2400 0 0 3600 2400 0 0 3600 7200 0 0 10800 7200 0 0 10800 4800 0 0 7200 2400 0 0
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
SET 24 31
3600 4800 0 0 7200 4800 0 0 7200 4800 0 0 7200 2400 0 0 3600
SET 85
28800 0 26400 30000 24000 0 21600 25200 86400 0 79200 90000 93600 0 86400 97200
SET 17 85
52800 0 48000 55200 28800 0 26400 30000 62400 0 57600 64800 48000 0 43200 50400
SET 33 85
52800 0 48000 55200 24000 0 21600 25200
PERFORM 172 193
AMOVE 1.102 10X1 1.44
ASUBTRACT 1.102 10X1 1.109 1.48
ASUBTRACT 1.101 10X1 1.106 1.49
AMOVE 1.4 40X1 1.26
AMOVE 1.19 40X1 1.27
AMOVE 1.112 40X4 1.71
SET 30
25200 6000 4800 33600 25200 6000 7200 36000 13200 3600 3000 17400 13200 3600
SET 15 30
3600 18000 12000 2400 2400 10800 13200 3600 3000 17400 12600 3000 3000 17400
SET 29 30
26400 7200 6000 34800 12600 3000 3600 18000 26400 7200 6000 34800
SET 31
19200 0 0 28800 19200 0 0 28800 9600 0 0 14400 9600 0 0 14400 9600 0 0 14400
SET 21 31
9600 0 0 14400 9600 0 0 14400 19200 0 0 28800 9600 0 0 14400 19200 0 0 28800
SET 85
30000 0 10800 39600 32400 0 13200 42000 16200 0 6600 21000 16800 0 7200 21600
SET 17 85
14400 0 4800 19200 15200 0 6000 21000 15600 0 6000 20400 32400 0 13200 42000
SET 33 85
16200 0 6600 21000 32400 0 13200 42000
PERFORM 172 193
AMOVE 1.100 10X1 1.44
ASUBTRACT 1.100 10X1 1.104 1.48
ASUBTRACT 1.103 10X1 1.111 1.49
AMOVE 1.3 40X1 1.26
AMOVE 1.18 40X1 1.27
AMOVE 1.112 40X4 1.71
SET 30
39600 10800 7200 50400 36000 7200 9000 52200 12000 2400 2400 16800 24000 4800
SET 15 30
6000 34800 12600 3000 2400 10800 25200 6000 7200 30000 12600 3000 3600 18000
SET 29 30
25200 6000 7200 36000 13200 3600 3000 17400 12000 2400 2400 16800
SET 31
28800 0 0 43200 28800 0 0 43200 9600 0 0 14400 19200 0 0 28800 9600 0 0 14400
SET 21 31
19200 0 0 28800 9600 0 0 14400 19200 0 0 28800 9600 0 0 14400 9600 0 0 14400
SET 85
46800 0 18000 61200 45000 0 16200 59400 14400 0 4800 19200 30000 0 10800 34600
```

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LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
...SET 17 85
   15000 0 5400 19800 32400 0 13200 42000 16200 0 9600 21600 32400 0 13200 42000
   SET 33 85
   16200 0 8600 21600 14400 0 4800 19200
   PERFORM 172 193
   AMOVE 1,102 10X1 1,44
   ASUBTRACT 1,102 10X1 1,106 1,48
   ASUBTRACT 1,103 10X1 1,110 1,49
   AMOVE 1,2 40X1 1,26
   AMOVE 1,9 40X1 1,27
   AMOVE 1,119 40X4 1,71
   SET 30
   33600 22800 19200 26400 50400 43200 43200 54000 33600 21600 24000 31200 36000
   SET 14 30
   28800 43200 54000 12000 9600 14400 18000 14400 12000 14400 19200 36000 28800
   SET 27 30
   43200 54000 12000 9600 12000 19600 14400 12000 9600 13200 16800 14400 9600 13200
   SET 31
   4800 0 0 7200 7200 0 0 10800 4800 0 0 7200 7200 0 0 10800 2400 0 0 3600 2400 0 0
   SET 24 31
   3600 7200 0 0 10800 2400 0 0 3600 2400 0 0 3600 2400 0 0 3600
   SET 85
   52800 0 66000 55200 93600 0 85400 97200 57600 0 56400 60000 79200 0 76000 82800
   SET 17 85
   26400 0 24000 27600 28800 0 26400 30000 79200 0 72000 82800 24000 0 21600 25200
   SET 33 85
   24000 0 21600 25200 26400 0 24000 27600
   PERFORM 172 193
   AMOVE 1,100 10X1 1,44
   ASUBTRACT 1,100 10X1 1,135 1,48
   ASUBTRACT 1,101 10X1 1,107 1,49
   AMOVE 1,1 40X1 1,26
   AMOVE 1,8 40X1 1,27
   AMOVE 1,136 40X4 1,71
   SET 30
   12000 9600 9600 13200 24000 19200 19200 26400 50400 43200 21600 39600 33600
   SET 14 30
   28800 24000 31200 16800 14400 14400 18000 43200 30000 38400 45600 43200 36000
   SET 27 30
   43200 54000 43200 36000 28800 39600 12000 9600 9600 13200 33600 28800 19200
   SET 40 30
   26400
   SET 31
   2400 0 0 3600 4800 0 0 7200 7200 0 0 10800 4800 0 0 7200 2400 0 0 3600 7200 0 0
   SET 24 31
   10800 7200 0 0 14400 7200 0 0 10800 2400 0 0 3600 4800 0 0 7200
   SET 85
   21600 0 19200 22800 43200 0 38400 45600 79200 0 74400 82800 57600 0 52800 60000
   SET 17 85
   31200 0 28800 32400 79200 0 72000 82800 86400 0 79200 90000 72000 0 64800 75600
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
SET 33 85
21600 0 19200 27600 52800 0 48600 55200
PERFORM 172 193
AMOVE 1,162 1031 1,44
ASUBTRACT 1,102 1031 1,105 1,48
ASUBTRACT 1,103 1031 1,111 1,49
AMOVE 1,2 4031 1,26
AMOVE 1,10 4031 1,27
AMOVE 1,116 4034 1,71
SET 30
26400 7200 4800 33600 26400 7200 6000 25200 36000 7200 5400 54200 37800 9000
SET 15 30
7200 50400 12000 3000 2400 10800 12000 2400 2400 16800 25200 6000 7200 34800
SET 29 30
26400 7200 7200 30000 36000 7200 7200 50400 13200 3600 3600 18000
SET 31
19200 0 0 28800 19200 0 0 28800 28800 0 0 43200 20800 0 0 43200 9600 0 0 14400
SET 21 31
9600 0 0 14400 19200 0 0 28800 19200 0 0 28800 28800 0 0 43200 9600 0 0 14400
SET 85
31200 0 12000 40800 32400 0 13200 42000 45600 0 10200 55400 45600 0 10200 59400
SET 17 85
15000 0 5400 19800 14400 0 4800 19200 32400 0 13200 42000 33600 0 14400 43200
SET 33 85
43200 0 14400 57600 16800 0 7200 21600
PERFORM 172 193
AMOVE 1,100 1031 1,44
ASUBTRACT 1,100 1031 1,135 1,48
ASUBTRACT 1,101 1031 1,106 1,49
AMOVE 1,1 4031 1,26
AMOVE 1,7 4031 1,27
AMOVE 1,116 4034 1,71
SET 30
24600 7200 6000 30600 36000 7200 9600 52200 25200 5000 4800 33600 24000 4800
SET 15 30
4800 33600 37800 9600 9000 52200 36000 7200 9000 52200 26400 7200 4800 33600
SET 29 30
12000 2400 3600 18000 37800 9000 7200 50400 13200 3600 3600 18000
SET 31
19200 0 0 28800 28800 0 0 43200 19200 0 0 28800 19200 0 0 28800 28800 0 0 43200
SET 21 31
28800 0 0 43200 19200 0 0 28800 9600 0 0 14400 28800 0 0 43200 9600 0 0 14400
SET 85
32400 0 13200 42000 45600 0 10200 59400 45600 0 10200 55400 20400 0 6600 34800
SET 17 85
44600 0 18000 61200 45600 0 16200 59400 31200 0 12000 41800 15600 0 6600 21600
SET 33 85
45000 0 14200 59400 16800 0 7200 21600
PERFORM 172 193
AMOVE 1,102 1031 1,44
```

LIST OF COMMANDS, DATA AND DIAGNOSTICS

```
ASUBTRACT 1,102 10*1 1,105 1,48
ASUBTRACT 1,101 1(*1 1,107 1,44
AMOVE 1,4 40*1 1,2P
AMOVE 1,20 40*1 1,27
AMOVE 1,112 40*4 1,71
SET 30
54000 43200 43200 54000 36000 28800 28800 39600 12000 9600 9600 13200 33600
SET 14 30
28800 19200 28800 14400 12000 12000 15600 43200 36000 36000        66000 14400
SET 26 30
14400 12000 15600 28800 24000 19200 28800 33600 25800 24000 31200 36000 28800
SET 39 30
43200 54000
SET 31
7200 0 0 10800 7200 0 0 10800 2400 0 0 3600 4800 0 0 7200 2400 0 0 3600 7200 0 0
SET 24 31
10800 2400 0 0 3600 4800 0 0 1200 4800 0 0 7200 7200 0 0 10800
SE  65
93600 0 46400 57200 94800 0 57000 68400 21600 0 19200 22800 54000 0 45000 55200
SET 17 65
28800 0 24000 27600 19200 0 72000 82800 28800 0 26400 36000 43200 0 43200 52400
SET 33 65
57600 0 52800 66000 74200 0 72000 82800
PERFORM 172 192
AMOVE 1,100 10*1 1,44
ASUBTRACT 1,102 10*1 1,104 1,48
ASUBTRACT 1,103 10*1 1,110 1,49
AMOVE 1,3 40*1 1,26
AMOVE 1,13 40*1 1,27
AMOVE 1,112 40*4 1,71
SET 30
43200 36000 28800 39000 14400 12000 12000 15000 43200 36000 43200 54000 12000
SET 14 30
9600 14400 19200 33600 28800 24000 31200 43200 36000 43200 54000 28800 24000
SET 27 30
19200 28800 12000 9600 9000 13200 24000 19200 19200 24000 16800 14400 12000
SET 40 30
15600
SET 31
7200 0 0 10800 2400 0 0 3600 7200 0 0 10800 2400 0 0 3600 4800 0 0 7200 7200 0 0
SET 24 31
10800 4800 0 0 7200 2400 0 0 3600 4800 0 0 7200 2400 0 0 3600
SET 65
72000 0 64800 75600 26400 0 24000 27600 88400 0 73200 90000 28800 0 26400 27600
SET 17 65
57600 0 52800 60000 86400 0 79200 90000 86400 0 43200 50400 21600 0 19200 22800
SET 33 65
43200 0 38400 45600 26400 0 26400 30000
PERFORM 172 192
STOP
```